TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

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IMPROVING INVENTORY MANAGEMENT OF SPARE PARTS BUSINESS IN A MULTI-ECHELON INVENTORY SYSTEM

Master of Science thesis

Examiner: prof. Jussi Heikkilä
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TIIVISTELMÄ

MIKKO RAHIKAINEN: Monitasoisen varastojärjestelmän hallinnan parantaminen varaosaliiketoiminnassa
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Diplomityön tutkimuskysymys kuului seuraavasti: *”Kuinka alan kirjallisuudesta löytyvällä teorialla pystytään pienentämään varastoihin sitoutunutta pääomaa ilman, että se laskee asiakastyytyväisyyttä?”* Tavoitteena oli tutkia kohdeyrityksen monitasoista varastointijärjestelmää kvantitatiivisella tutkimusmenetelmällä.

Ensimmäiset kappaleet pohjustavat sekä kuvailevat tutkimusaluetta tieteellisen kirjallisuuden kautta. Osuus on tärkeä myöhempää empiiristä osuutta varten, jotta empiirisessä osuudessa löydetään kohdeyrityksen ongelma-alueet sekä alueet, mihin kohdeyrityksen pitää keskittyä.

Työn empiirinen osuus alkaa kohdeyrityksen nykyisen varastointijärjestelmän sekä -periaatteiden kuvaamisella. Tämän jälkeen työ arvioi eri maakohtaisten varastojen suorituskyvyn eri mittareilla mitattuna, jotta parhaimmat ja heikoimmat nimikekategoriat saadaan selville. Kun nykytilanteen analyysi on tehty, toimintaa parantavat toimenpiteet arvioidaan seuraavissa kappaleissa.

Tulokset kertovat, että jokaisella maakohtaisella varastolla on todella paljon liikkumattomia tai hitaasti liikkuvia varaosanimikkeitä varastoissaan. Alan kirjallisuus ehdottaa, että maakohtaiset varastot keskittyvät vain suuren kysynnän nimikkeisiin ja keskusvarasto toimittaa suoraan paikallisesti hitaasti liikkuvia nimikkeitä. Tarkempi analyysi osoitti, että maakohtaiset varastot voivat vähentää varastotasojaan melkein 25% lähettämällä globaalisti liikkuvia, mutta paikallisesti liikkumattomia nimikkeitä takaisin järjestelmän ylävirtaan. Varaston arvoa saadaan vähennettyä huomattavasti, vaikka paikallisesti paljon liikkuvien nimikkeiden varaston arvoa nostetaan.

Datan keräämisen sekä analysointiprosessin aikana löytyi myös muita kehityskohteita. Ensimmäiseksi, raportointijärjestelmä tarvitsee parannuksia, koska se ei näytä suorituskykymittareita lokaalien indikaattoreiden mukaan. Raportointijärjestelmän antamat globaalit indikaattorit eivät anna tarpeeksi informaatiota etulinjoille. Lisäksi, raportointijärjestelmästä puuttuu suuri osa toimitettuja rivejä samalla sisältäen rivejä, mitä sinne ei kuulu. Toisekseen, kohdeyrityksen tunnuslukumittareita kannattaa päivittää. Tunnuslukumittareihin kannattaa lisätä täydellisten tilausten mittari, jotta yritys saa parempaa informaatiota suorituskyvystään. Kolmanneksi, etulinjojen ostokäytäntöjä pitää muuttaa kohdeyrityksessä. Keskusvarasto toimii tulosten valossa paikallisesti hitaasti liikkuvissa nimikkeissä paremmin kuin pakalliset toimittajat.

ABSTRACT

MIKKO RAHIKAINEN: Improving inventory management of spare parts business in a multi-echelon inventory system
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The research question of this thesis was: *How to reduce current inventory levels by actions found from literature without decreasing customer satisfaction?* The aim was to investigate the Case Company's multi-echelon inventory system through quantitative methods. To address the research question, relevant literature research is also needed.

In the first chapters, a theoretical background is conducted as the lateral empirical phase. Scientific journals and articles are used as the base of the theoretical background. The purpose of the theoretical background is to cover the most important issues of warehousing management and item stocking decisions in a multi-echelon inventory in respect to the situation of The Case Company.

The empirical part of this thesis starts with a description of the case company's current inventory management principles. Then, the current situation is evaluated by key performance indicators in order to find the most problematic item groups. Data for this part was gathered from the Case Company's reporting system. Upon knowing the current situation, actions for improvement are then analysed in a subsequent empirical phase.

The result of the current situation is that every front line unit stock value consists mostly of locally non- or low-moving items in which case the relevant literature recommends downstream echelons to concentrate on high-moving items and distribution center (DC) distributes locally low moving items. When evaluated which locally low-moving items are returnable, the results show that front line units could reduce their inventory value by almost 25% even though the stock levels for high moving items were increased.

During the data gathering and analysing process, multiple areas of improvements were also found. Firstly, the reporting system needs improvement because it does not show front line unit performance by local indicators. Furthermore, the reporting system does not include all order lines in its reports and some of the ordered lines are incorrect. Secondly, the Case Company should review its KPIs. The Case Company should add perfect order KPI indicator to achieve more accurate information about its performance. Lastly, purchasing policies need to be changed in front line units. The distribution center has shown its superiority especially in low moving items and thus it is recommended that DC is used more than it is currently as a default vendor.

PREFACE

This Master of Science thesis was made over the course of seven months between October 2015 and April 2016. My journey to completing this thesis was not the easiest but it has most certainly been educational. Academic writing or writing in general has never been an area that I consider myself well-skilled in, but I believe that if one is motivated and surrounded by great people, then anything is possible.

First of all, I would like to thank Professor Jussi Heikkilä for guiding me while I was compiling my thesis. Secondly, I want to thank many people in the case company who have given me useful contributions to this thesis. Thirdly, I want to thank M.A. Kandace Hawley for her help with polishing/editing the English of this text.

However, above all, I would like to thank the whole student organization of TUT, which has given me more than I could have ever imagined. All the entrusted positions and communities that I have been part of have allowed me to maintain a good balance between vigorous studying and leisure.

Last but not least I want to give many thanks to my family who has supported me during my studies. My journey from freshman year to graduation has been long and arduous but my parents have always believed in me.

Tampere, 27th April 2016

Mikko Rahikainen

CONTENTS

LIST OF SYMBOLS AND ABBREVIATIONS

3PL	Third party logistics
APAC	Asia Pacific
COGS	Cost of goods sold
DC	Distribution center
EDLP	Everyday low price
EMEA	Europe, Middle East and Africa
ERP	Enterprise resource planning.
FLU	Front Line Unit. Warehouses which are closest to the customer
OFR	Order fill ratio
SKU	Stock keeping unit
TIDS	Total Inventory days of supply

1. INTRODUCTION

1.1 Research background

Case Company has tens of thousands of spare part items in multiple locations. Excess stock in different inventories does not increase the value of these items, rather their value may decrease (Happonen 2011, p. 1). In contrast to excess stock, each shortage offers a greater impact. Stock-out costs might be more expensive and poor inventory management reduces customer satisfaction and increases operating costs. It can be said that if inventory management is at a good level, it is the mark of well-managed organization. (Costantino et al. 2013, p. 95; Stevenson 2009, p. 549)

Since part availability is crucial for providing a timely service, the after-sales services companies face the difficult task of being responsive while managing the inventory effectively and keeping the inventory holding costs low. (Satır et al. 2012) Traditional inventory theory convinces that if we want to increase service level, we need to increase inventories and therefore increase the costs of inventory. Recent developments will deny this and prove that both can be better simultaneously. (Kalchschmidt et al. 2003; Paakki et al. 2011; Simchi-Levi et al. 2004)

From a theoretical perspective, the uncertain demand creates significant difficulties both in forecasting and stock control. Spare part management is extremely important for organizations that are holding relevant inventories with tremendous cost implications. (Syntetos et al. 2009, p. 293) The question of how to optimize a multi-echelon inventory problem has been an ongoing debate since the 1950's. Despite the huge amount of spare part inventory literature, most of the studies are focusing on mathematical frameworks that do not work in practice due to their complexity. Only a few discuss implementing solutions. (Botter & Fortuin 2000; Syntetos et al. 2009; Clark & Scarf 2004; Bacchetti & Saccani 2012)

The aim of this thesis is implement founded solutions from literature to Case Company decision-making to improve their spare part management, and specifically their inventory turnover without decreasing current service levels. The Case Company has realized that their inventory holdings are vast and they want to find suitable solutions for this without decreasing customer satisfaction or their service levels.

1.2 The Case Company

The Case Company has more than 250 employees and its annual turnover is more than 50 million so it can be considered as a large enterprise. (European Union 2015, p. 11). The Case Company is divided into three major business units and they are providing different types of solutions for cargo handling. Furthermore, every business unit has a large portion of equipment and services as their product portfolio. Sales of service were over 20% of the total sales in the year 2014.

The Case Company's strategy states that it wants to give solutions for customer needs and exceed their expectations. The Case Company strongly emphasizes improving their service operations. In doing this, they have recently launched new service agreements for their customers. Customers may choose different types of services from normal annual inspections to complete service agreements.

1.3 Research problem & objectives

The goal of this master's thesis is to evaluate current European Front line units (FLUs) inventories and implement actions for improvement that are found in literature without decreasing current customer satisfaction. Furthermore, partial optimization is not an option. In other words, recommended actions improve the system as a whole, not only singular warehouses.

Case Company has three major geological areas within the regions of Europe, Middle-East and Africa (EMEA), Asia Pacific (APAC) and America. Currently, the Company has one major Central warehouse in central Europe and two minor Central warehouses in northern Europe. Within a couple of years, their mission is to launch two new major central warehouses; one in the APAC area and the other in America. This thesis work will be used as a guideline for region multi-echelon inventory management. In recent years, the Company has done a lot of work to improve their service organization's profit margin and in doing so, the realization that inventory turnover must be improved emerged because current inventory levels are holding too much invested capital. Thus, to express the research problems of this thesis:

- From a company competitiveness perspective, it is crucial that its spare part multi-echelon inventory serves customers at high level with low minimum costs.

To find a solution for the dilemma mentioned above, the research question would be following:

- **How to reduce current inventory levels by actions found from literature without decreasing customer satisfaction?**

To find solution for the research question we need to find solutions for following sub questions:

- What is the nature of spare part inventory management?
- What should be taken into account to reach acceptable inventory turnover in a multi-echelon inventory?
- What are current inventory levels and customer satisfaction at front line unit inventories?
- Where should the items be stocked and how much should be stocked within each storage location?

1.4 Scope of research

The scope of this thesis focuses on three EMEA regions after-sales office warehouses, also known as front line units (FLUs). Therefore, new machine production inventory is excluded from this thesis, because the entire focus of this work is on spare part inventory management and planning. Also, the supplier bases and their performance is excluded. Furthermore strategic warehouse decisions, for example warehouse physical locations or item categorizations, is excluded from this study. The main reason for these restrictions is that suppliers' actions are part of the purchasing team. In addition, including all the parties in this thesis would not have been possible given the time frame. Figure 1 presents the scope of this thesis.

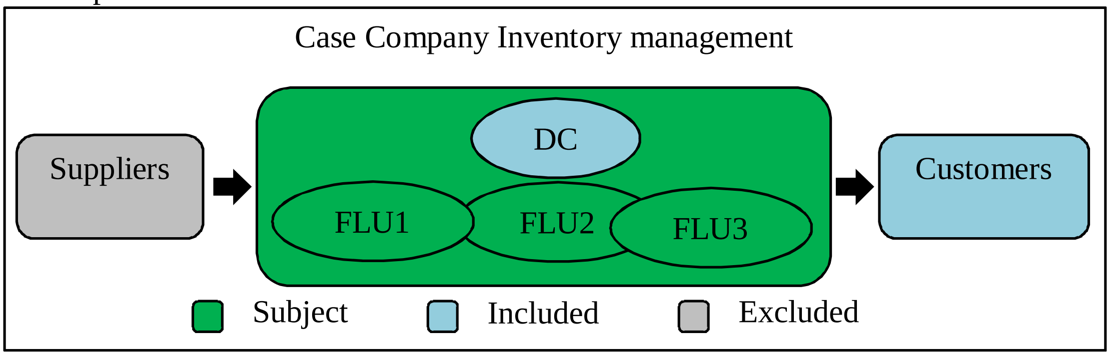


Figure 1: *The scope of this thesis*

As the above figure illustrates, the scope of this thesis is Case Company's three front line units. Thus, the factors which have an additional impact are the distribution center and Case Company's inventory management. The distribution center is not considered, but its influences on the FLU's inventory management are noted.

1.5 Research methodology

This thesis is an applied case study research and its purpose is to improve a specific problem in inventory management. The philosophy behind this thesis is realism in which the research point of view is objective, but since the researcher has been working for the Case Company, this and other cultural experiences have an impact on the research. The approach of this research is deductive, in that it firstly introduces the basic theories and challenges in the business of spare parts and findings are applied to the Case Company. On the other hand, the approach of this thesis can be seen as operation management research because this thesis concentrates on solving practical problems. (Saunders et al. 2009, p. 138-149; Holmström et al. 2009, p. 77)

First part of this thesis is a literature review, which describes the phenomenon behind the subject. Data for the first part is gathered from scientific journals and literature. The second part of the thesis empirically investigates a contemporary phenomenon within real contexts of the Case Company; therefore this can be seen as an explanatory case study as well. (Saunders et al. 2009, p. 146)

Yin (2003, p. 46) claims that case studies should have more than one case company or organization because in single-case research, findings are highly generalized and therefore, multiple case studies are preferable. Alternatively, Yin states that single cases can be used if the case is critical, extreme or unique. However, because of this thesis' specific characteristics, only one case company is used.

The second part describes the Case Company's spare parts logistics and management systems and processes. Data is gathered from the company's documentation. The second part also includes a quantitative data analysis from company databases. The purpose of the quantitative data analysis is to make the raw data useful and find answers that address the research question. Thus, because only quantitative data is gathered, this thesis can be seen as mono-method research. The time span of this thesis is cross-sectional, because the data gathered is from the year 2015. (Saunders et al. 2009)

1.6 Research structure

The following chapter provides a theoretical background for the study which is based merely on the literature review. The chapter describes the basics of the spare parts business. The aim is to point out phenomenon behind stocking decisions in spare parts businesses.

The third chapter presents the current situation in the Case Company. It describes the current supply chain structure of its supply chain. In addition, it will introduce current stocking decisions and item classification methods in the Case Company. Chapter three illustrates how quantitative data is gathered from reporting systems. The third chapter also includes the current situation of the Case Company. Furthermore, it evaluates current stocking levels and defined performance measurements in this thesis' evaluated front line units.

Chapter four concentrates on the evaluation of the data analysis and gives recommendations for future actions to achieve the given targets. Moreover, it evaluates how given recommendations will affect stock levels and certain key performance indicators.

The final chapter presents the conclusion of this thesis. First, the main results of the stocking decisions are summarized. After that, the whole study and its feasibility and relevancy are assessed in consideration of the original research question. Finally, future research recommendations are also given.

2. THEORETICAL BACKGROUND

2.1 Spare parts definition

Large machines and technical installations always need maintenance because some parts of the machine may fail and other items need to be replaced periodically. These parts are called spare parts. Furthermore, they play a vital role in maintaining and ensuring the reliability of any equipment. (Gopalakrishnan & Benerji 2004, p. 232; Fortuin & Martin 1999) Spare part includes everything that needs to be replaced during the operating life of the equipment, such as hoses, wires, bolts, filters, engines and gearboxes. (Gopalakrishnan & Benerji 2004, p. 232)

Spare parts can be divided into two main categories: repairables and non-repairables. Repairables, also known as rotables, include parts that are usually expensive. Rotables parts are complex components and they can be repaired and reused in other machines, whereas repairables items may have a limited number of repairs. On the other hand, consumables, also called expendables, are scrapped after removal, such as gaskets or filters, and they are replaced by a new one every time. (Fortuin & Martin 1999; Gu et al. 2015)

The service lifecycle of a product is much longer than its production lifecycle. The service part lifecycle can be divided into three phases: the initial phase, the normal phase and the final phase. In the initial phase, the product is new and parts have never been used in the products before. Therefore, there is very little of knowledge about their failure rates or behavior in practice. In the normal phase, knowledge of spares is increased, items can be recognized and demand patterns are identified. In the third phase, the production of the product is discontinued, but service lifecycle could continue for decades. (Fortuin & Martin 1999)

The key characteristics of spare parts are demand unpredictability, a high variety of items and the trade-offs between inventory costs and service levels (Costantino et al. 2013, p. 95; Stevenson 2009, p. 550-554). The demand unpredictability refers to times when an item fails when it otherwise should not fail. On the other hand, items like filters are really predictable, because they need to be replaced periodically. Moreover, items such as gearboxes are expensive but regular nuts and bolts are not. Inventory decisions in a spare part service business are critical because the lack of items can be really expensive but on the other hand keeping everything at the warehouse increases inventories exponentially. (Stevenson 2009, p. 550; Gu et al. 2015)

The classifications of stock keeping units (SKUs) vary widely and two main questions need to be considered: 1.) What are the item classifications? 2). And how the borders between classes are determined (van Kampen et al. 2012)? Generally, industrial spare parts are classified according to their criticality for the functioning of a piece of equipment or by their annual value. (Syntetos et al. 2009, p. 294)

2.2 Cost of inventory

A cost of inventory includes three main components which are ordering costs, holding costs and shortage costs. Ordering costs are costs which are caused by ordering and receiving the inventory and it varies with the actual placement of an order. Ordering costs include order preparations, invoice handling and receiving the goods. It depends on the total annual flow through the warehouse and it is usually calculated as a fixed dollar amount per order, regardless of order size. (Stevenson 2009, p. 556)

Holding costs (also known as carrying costs) are costs which are related to physically having the goods in the storage for a certain period of time. Holding costs include different costs such as insurance costs for a warehouse and stored items. It also includes the costs of obsolescence, breakage, interests of invested capital and depreciation. It also includes fixed costs such as warehouse rent, heating and lighting. (Simchi-Levi et al. 2004, p. 80; Stevenson 2009, p. 556) According to Stevenson (2009, p. 556) normally, holding costs are between 20-40 percent of the value of an item. Moreover, a carrying cost can be stated as a dollar amount per unit.

In addition, Stevenson (2009, p. 556) defines that the shortage costs occur when demand exceeds the supply of the inventory on hand. These costs include the opportunity cost of losing customer goodwill, any late charges, the cost of machine downtime and/or the cost of not making the sale. Shortage costs may be difficult to measure and usually they need to be subjectively estimated.

It is common that companies try to lower their inventory value through different actions. Some try to lower holding costs and others try to lower shortage costs. Fisher (1997) states that companies should concentrate on their inventory by first defining their products. If the item is functional in which it has a regular demand and low profit margins, otherwise known as commercial products, the cost of inventory improvements is found from holding and carrying costs. When the item is relatively common and it is highly competitive, optimal improvements are achieved with a physically efficient supply chain and high inventory turnovers. On the other hand, if the item is innovative in which case it has high volatility and profit margins, the largest costs will occur through shortage costs.

2.3 Demand fluctuation

Happonen (2011, p. 27) defines that spare part inventory demand is the most difficult to predict. Some items do not have any demand within a certain time period, while during other times, the demand might be substantial. Therefore, items can be categorized by demand, which are occasional but not periodic demand, regular demand, peaky demand and slow demand. These categories are illustrated in Figure 2.

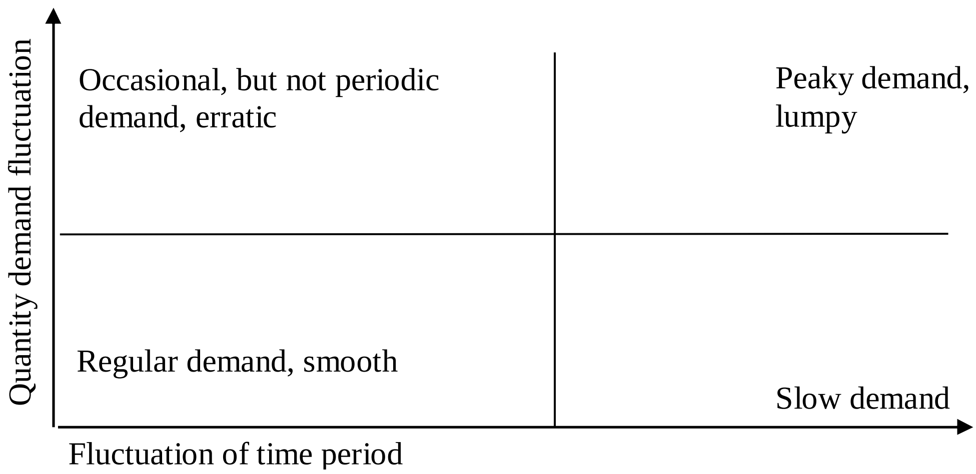


Figure 2: *Different demand categories (Happonen 2011p, 119)*

Sales offices need to maintain customer satisfaction and a decent level of service. Therefore, they need to predict the future demand and if it differs from the forecasted demand, then the sales office's inventory levels fluctuate as well. This will be repeated at the upstream of the supply chain and it occurs larger for upper echelons. Sales offices can use safety stocks to counteract against the demand fluctuation. This demand fluctuation is called the Bullwhip effect. (Lee et al. 1997; Happonen 2011, p. 120)

End customer demand fluctuation and safety stocks are not the only reasons why the bullwhip effect occurs. Other reasons for this phenomenon are: demand forecast errors, inflate orders, lead time variations, order batch sizes and price fluctuations. Multi-echelon inventory systems can counteract against the bullwhip effect when actual demand information from downstream sites is available for upper echelons. When an upper level echelon future demand forecast relies only the lower echelon's order history, data is duplicated because the lower echelon's estimates are already taking into account the possible safety stock. (Lee et al. 1997, p. 8; Simchi-Levi et al. 2004, p.23) Secondly, long lead times cause a small change in demand causes significant adjustments to re-order points and quantities. Inflated orders refer that if sales offices anticipate that a certain product is temporarily on shortage, they will order larger amounts to avoid their stock outs. (Lee et al. 1997, p. 8; Simchi-Levi et al. 2004, p.23)

Batch ordering is common when an item price is low. Therefore, companies order batches to save on handling and transportation costs. Moreover, some suppliers are forced to buy only full batches, because it is not economically reasonable to sell the requested exact amount of items. Furthermore, some suppliers also provide quantity discounts. Therefore, customers are willing to buy larger batches. These factors make it so that customers will order large batches within expanded time intervals which causes forecast errors. Simchi-Levi (2004, p.26), Lee et al. (1997, p. 9) and Fisher (1997, p. 113) suggest that sales offices should use the everyday low pricing strategy (EDLP). When EDLP is used, sales offices offer an item at a consistent price rather than offering quantity or seasonal price promotions. This will smoothen the consumption, because discounts will generate peaks in demand.

The research of Kalchschmidt et al. (2003) focuses where no information is provided along the supply chain and various echelons are completely decentralized. The conclusion of the research is that demand fluctuation occurs with specific items because the regular demand comes from orders by many small customers and an irregular demand is the result of a few large orders from the largest customers or lower echelons. Therefore, it would be valuable to gather information from largest customer beforehand.

However, gathering demand information beforehand does not only include information about what needs to be gathered from the largest customers. Gu et al. (2015, p.107) and Costantino (2013) found out that forecasting is more accurate if the company takes in account the machine hours, the failure rate of items, and the aging of parts, while focusing on impending demand. With these actions, a service company could analyze the failing parts and implement counteractions. For example, if a gearbox manufacturer claims that the failure rate of a gearbox increases significantly after 10,000 operation hours, the service company could compare these elements with their own machine hours and make proactive actions.

The Bullwhip effect significantly affects companies' inventory levels, which increases the invested capital in warehouses. With reliable, centralized demand information, companies can overcome the phenomenon. Simchi-Levi et al. (2004) & Kalchschmidt et al. (2003) came up the same conclusion: when end customer demand information is provided for each stage of the supply chain, the bullwhip effect can be significantly reduced. On the contrary, Zhao & Zhao (2015) researched human decision-making behavior in multi-echelon management and they found out that full information sharing does not make a significant difference than the scenario of no information sharing. The reason for this is the managers' limited capacity in processing all the information.

Many researchers implement a vendor managed inventory (VMI) to reduce the bullwhip effect. Using VMI, the vendor handles the warehouse and makes the purchase orders. (Simchi-Levi et al. 2004; Stevenson 2009) However, due to the scope of this research, VMI inventory is not researched.

2.4 Multi echelon inventory system

When the business is global and customers are spread all over the world, multi-echelon inventory structure is a standard requirement. If the company has only one distribution center for spare parts, the carrying costs may exceed the price of the part. Therefore, it is reasonable to keep sub-inventories because total availability depends on the sum of the availability of what one site provides. Furthermore, different sites have different customers, so the inventory varies on different sites. (Costantino et al. 2013) The structure of simple multi-echelon inventory systems is represented in Figure 3.

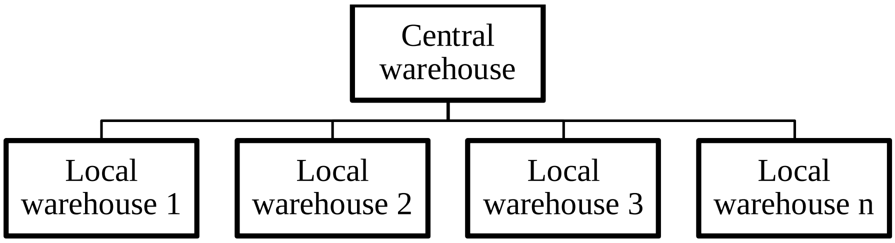


Figure 3: *Multi-echelon (two-echelon) inventory system (Adopted from Costantino et al. 2013, p. 97)*

Costantino et al. (2013) defines that it is not economically reasonable to stock low-demand, high-value items near every customer, therefore a central warehouse is needed. Companies usually have budget limits on warehouse levels, so it is crucial for local warehouses to know the nearby customer needs. Furthermore, if some items have a lot of stock outs, a local warehouse could use a local vendor to replenish the stock to fulfil the demand. (Kalchschmidt et al. 2003; Costantino et al. 2013)

Comparing a multi-echelon system with a regular inventory system in which the central warehouse works as the supplier for the country locations, there are often responsible people for distribution center inventories and other responsibilities for the country warehouses. Local inventory planners often work individually and drive only individual performance which impacts the overall performance. Therefore, the multi-echelon system fits better because it is a system-wide approach to set the inventory levels. In addition, Shill (1990, p. 91) adds one important factor to multi-echelon inventories: local warehouse inventories need to reflect the local customers' specific needs. Despite the benefits of the multi-echelon approach, lack of collaborative processes between inventories can jeopardize these benefits. (Altay & Litteral 2011, p. 295)

On the other hand, big companies such as Philips and Apple have reduced their national warehouses and use regional distribution centers which serve much wider geographical areas. It is a statistical fact that consolidating inventory into fewer locations can reduce the total inventory requirements. It is called "square root rule". An example, if a company has 25 warehouses and reduces them to four. Taking square root from both values, the reduction in inventory is circa 5:2 (60%). (Christopher 2005, p. 215) notes that reducing local warehouses could be problematic in the spare part business because customers require a rapid response to their needs. Furthermore, the spare part business could include large and heavy parts in which the costs of logistics are steep, hence greater distances could jeopardize the benefits of centralized warehouses.

2.5 Inventory replenishment

Management needs to think about two functions concerning their inventory. One is to keep track of the items on hand and the other is decision-making such as when and how much to order. There are two types of inventory counting; periodic and perpetual. Under a periodic system, the inventory is calculated at periodic intervals in order to decide how much needs to be ordered of each item. A perpetual inventory system continuously keeps track of removals from inventory and when the amount on hand of a certain item reaches a predetermined minimum, a fixed amount of items is ordered. This is also known as (s-1, s) policy. (Stevenson 2009, p. 554; Muckstadt & Sapra 2010, p. 185) Both systems have their advantages and disadvantages.

Periodic system advantages are that orders for many items occur at the same time which can result in savings in ordering costs and in processing. On the other hand, disadvantages involve the lack of control between reviews. Therefore, management needs to protect against shortages between review periods by carrying safety stock. (Stevenson 2009, p. 553) The advantage of the perpetual inventory type is the continuous monitoring of inventory. Another advantage is the fixed-order quantity in which management can order the economically optimal order quantity (EOQ). The main disadvantage of the continual systems is its record keeping costs. (Stevenson 2009, p. 554)

EOQ defines the fixed order size that will minimize the sum of the annual costs of both holding inventory and ordering inventory. The equation is also known as the Wilson Formula. It takes into account the annual demand, the fixed cost per order, the annual holding cost per unit, and the order quantity. The equation involves a number of assumptions: only one part is involved, annual demand is known, demand rate is constant, lead time is constant, orders are received in a single delivery and there are no quantity discounts. (Stevenson 2009, p. 559-564)

The customer does not care about the supplier's lead time variations; they want to receive ordered items on time. Therefore, there are strong connections between the stock on hand and the service level. If the company tries to keep everything in stock, the inventory costs increases significantly. (Stevenson 2009, p. 576; Christopher 2005, p. 68) Service level is a probability that inventory will suffice the demand. It costs money to hold safety stock; therefore, managers need to balance between the costs of holding to pre-empt stock-out risks. Stevenson (2009, p. 572) defines the service level as the following:

$$Service\ level = 100\ \% - Stockout\ risk$$

In inventory management, a probability of demand normally forms into a symmetrical bell shape normal distribution where the mean value is at the center point. The normal distribution shape is illustrated in Figure 4.

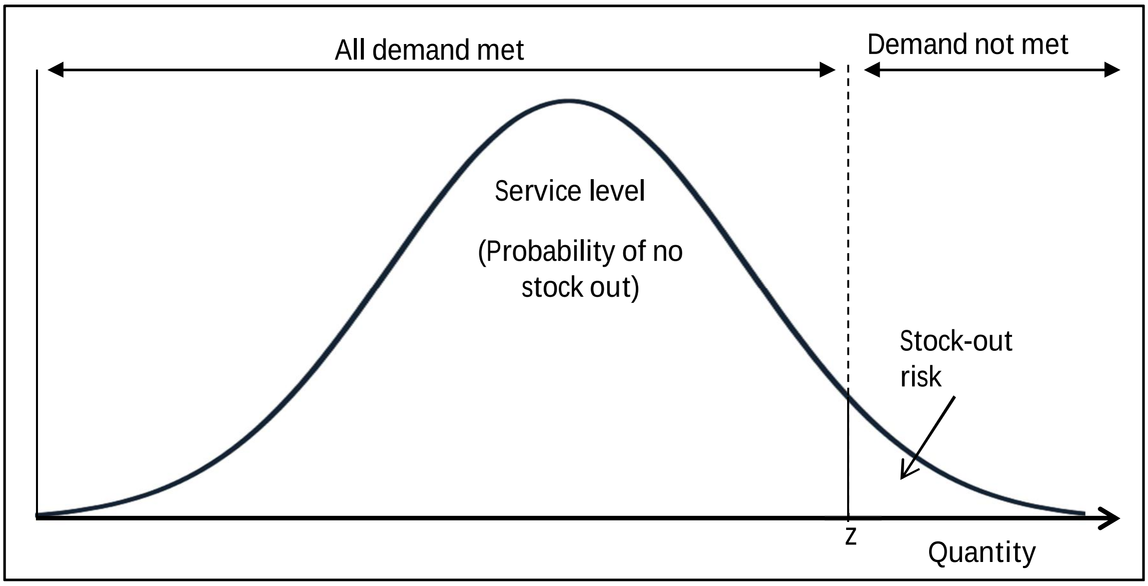


Figure 4: *Normal distribution curve and stock-out risk (Stevenson 2009, p. 565)*

A basis of using normal distribution when forecasting demand during ordering lead time is standard deviation. It describes the dispersion of occurrences in the normal curve. The higher the standard deviation is, the flatter the bell shape is. (Stevenson 2009, p. 572; Sakki 1999, p. 129) Standard deviation can be computed by the formula:

$$\sigma = \sqrt{\frac{\sum F_i D_i^2}{n}}$$

Where,

- σ = Standard deviation
- F_i = Deviation of event from mean value of event i
- D_i = Deviation of event from mean value of event i
- n = Total number of observation available

Standard deviation can be computed also with spreadsheets such as MS Excel. Standard deviation is used when calculating safety stock; required quantity can be calculated with the following:

$$Safety\ Stock\ (SS) = z\sigma_{dLT}$$

Where,

- z = Safety factor
- σ_{dLT} = Standard deviation of lead time demand

Safety factor (z) determines the probability of stock-out. The general rule is that the greater desired service level, the greater is the safety factor z. For example, a company estimates that if it wants to perform with 93% service level, safety factor z is between 1.47-1.48. (Stevenson 2009, p. 572)

2.6 Spare parts inventory management

Good inventory management can offer significant invested capital cost reduction and improve customer satisfaction. The objective to any inventory management is to achieve sufficient service levels with minimal inventory investment and administrative costs. Too much inventory consumes physical space and increases the possibility of damage, spoilage and loss. (Koumanakos 2008; Stevenson 2009, p. 586; Huiskonen 2001) To understand the challenges of spare part inventories, service parts management needs to identify those challenges. In the research of Boone et al. (2009) Delphi, inventory managers answered the challenges of spare part inventory management as represented in Table 1.

Table 1: *Top ten challenges of spare part inventory management (Adopted from Boone et al. 2009)*

Rank	Service part Challenge	Main causes
1.	Lack of a system or holistic perspective	Complex systems from new product development to after sales and customer support.
2.	Inaccuracy forecasts	A part failure causes sporadic and high variable demand.
3.	Lack of system integration among supply chain	Difficulty of satisfying customer demand because lack of information such as availability
4.	Lead time variability	Varying lead times result in use of safety stock inventories
5.	Product revision data	Service providers are unaware of configuration changes until an engineer is on site
6.	Service part obsolescence	Stored spare part becomes obsolete as new revision is launched
7.	Planning for service requirements for old products	Products generate needs for service although production is over. Service need to determinate final buy of parts, find repairers for ageing parts and launch policies for managing reconditioned units
8.	Planning for new product introduction	A Service part planning is difficult in the initial phase of life cycle. Now information about the failure rate of parts.
9.	Maintaining repair cycle process discipline	Complex process needs to manage carefully. How to get efficient repair cycle.
10.	Planning the location and physical distribution of service parts	Strategic decisions are key challenges to achieve desired level of customer service.

As can be seen, there are multiple factors which make spare part inventory management difficult. Additionally, the founded issues can be broadly categorized together. Product revision data (5.), service part obsolescence (6.), old product service planning (7.) and planning for new product development (8.) are all related to a new product development process. Furthermore, the inaccuracy of forecasts (2.), repair cycle process (9.) and distribution of service parts (10.) are logistics and planning challenges.

Generally, the idea that something is obsolete means that it is no longer useful. (Grover & Grover 2015, p. 300) Spare part obsolescence can occur if product design and revision updates changes the product structure significantly. In this case, new revision for an old machine could replace the old item and therefore spare part inventory becomes non movable and increases the inventory value. Obsolescence risk is higher for automotive and IT parts because of fast product development. (Pfohl & Ester 1999; Roda et al. 2014; Boone et al. 2009)

Stevenson (2009, p. 586) highlight lead time variations and forecast errors as two main factors for planning challenges as well. In addition, there are other multiple sub reasons which affect forecast errors such as uncertain part failures, accidents, and a large number of parts. Other challenges for inventory management are limited budget and warehouse space. (Gu et al. 2015, p. 102) Especially in a spare part business, the demand fluctuation is difficult to forecast. Because of the characteristics of spare parts, it is widely discussed that mathematical models are not suitable for spare parts. (Botter & Fortuin 2000; Paakki et al. 2011, p. 165) Puurunen et al. (2014) made in their research an interesting conclusion; it was that lead time variation decreases the service level more than demand variation. On the other hand, in their research, only 100 items were evaluated. Therefore, generalizing the results is questionable.

In production, inventory levels are defined by production planning. Therefore, it differs widely from spare parts management. Consequently, straight answers to simple questions in spare parts management are hard to get. Bacchetti & Saccani (2012) discuss about an integrated view which encompasses spare part classification, demand forecasting, inventory management and performance assessments; all within this view should be handled as a whole that affects the overall effectiveness in a company’s spare part inventory performance. This framework is illustrated in Figure 5.

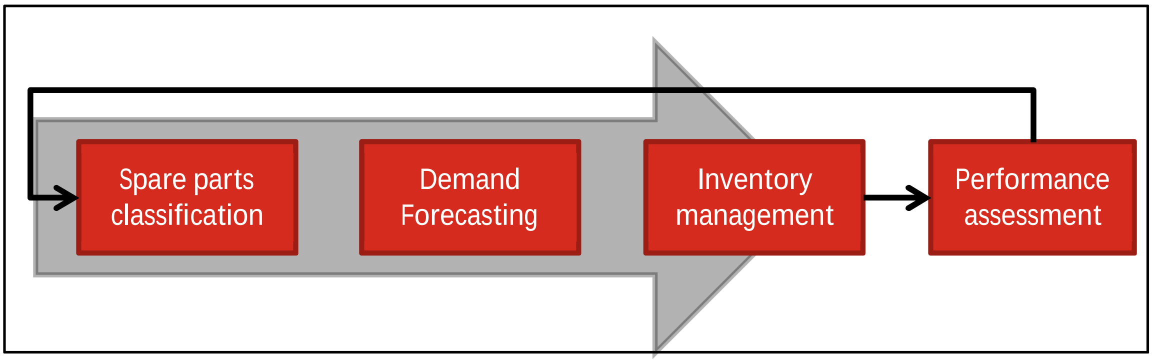


Figure 5: *An integrated approach to spare part management (Bacchetti & Saccani 2012, p. 773)*

This integrated perspective shows the relations between the steps and decisions on different aspects. These decisions should be made with a systemic perspective. An item categorization framework needs to be developed so management could find the improvement areas more closely. (Paakki et al. 2011, p. 165; Bacchetti & Saccani 2012) To handle thousands of stock keeping units (SKUs) in spare part inventories, there is a need to categorize items in a more varied manner. Huiskonen (2001, p. 129) describes the four most critical control characteristics in spare parts which are: criticality, specificity, demand pattern and value of the spare part. Management needs to select a few of the most relevant control characteristics to make item classification. (van Kampen et al. 2012; Huiskonen 2001)

With a differentiated approach, every item class should be treated by different demand forecasting and inventory management techniques, and three basic questions need to be answered: which parts, where and how many of them should be stocked? (Botter & Fortuin 2000, p. 656; Bacchetti & Saccani 2012) It is notable that management needs to consider trade-offs between the complexity of the system and the performance. Systems that are too complex cause management to not be able to handle or understand the system properly. Therefore, tools need to be realistic and easy to use. (Huiskonen 2001, p. 126) Finally, performance assessments should be understandable to management and they should also indicate improvement areas for further development to the inventory management. (Bacchetti & Saccani 2012) Following sub chapters describes the framework steps of Bacchetti & Saccani (2012) more specifically.

2.7 Item categorization

A classification of spare parts helps to determine the requested service requirements for different spare part classes. With proper classifications, management can set different targets, use different forecasting methods and make different stocking decisions in different categories. (Bacchetti & Saccani 2012) The categorization can generally be divided into two main areas: statistical methods and judgmental methods. Statistical methods are based on quantitative analysis and forecasts. Whereas, judgmental methods are based on the criticality of items. Characteristics are based mainly on volume, products, customer and timing. (van Kampen et al. 2012) When management has the detailed information about performance measurements by categorization, actions can be taken. Categorization can be either qualitative or quantitative values, for example supply variance, demand areas or product lifecycle. In this thesis, only quantitative data is researched.

Managers need to choose the most acceptable method for their business. In the research of van Kampen et al. (2012), spare part inventory managers are focusing on different characteristics which are gathered in Appendix 1. As the appendix shows, the most commonly used volume characteristic is demand volume, which is used in the ten of the twelve researched inventory management situations. Other characteristics used are unit costs (used eight times of twelve cases) and criticality to the customer (eight of a twelve). Following two sub-chapters will describe how stock keeping units are defined in these cases.

2.7.1 Statistical methods

Traditionally stock keeping units (SKUs) are classified by some measure of importance, for example the annual dollar value or the annual demand. The ABC–approach categorizes items to A - very important, B - moderately important, and C - less important items/parts. (Scholz-Reiter et al. 2012; Stevenson 2009, p. 556; van Kampen et al. 2012) The ABC approach is a Pareto-like categorization, where the most important items account only 10-20 percent of the number of items but they generate 70-80 percent of the annual dollar value. At another end of scale, C items cover around 80 % of the items, but they generate only 10-20% of the annual dollar value. (Stevenson 2009; Muckstadt & Sapra 2010) Figure 6 illustrates the ABC categorization.

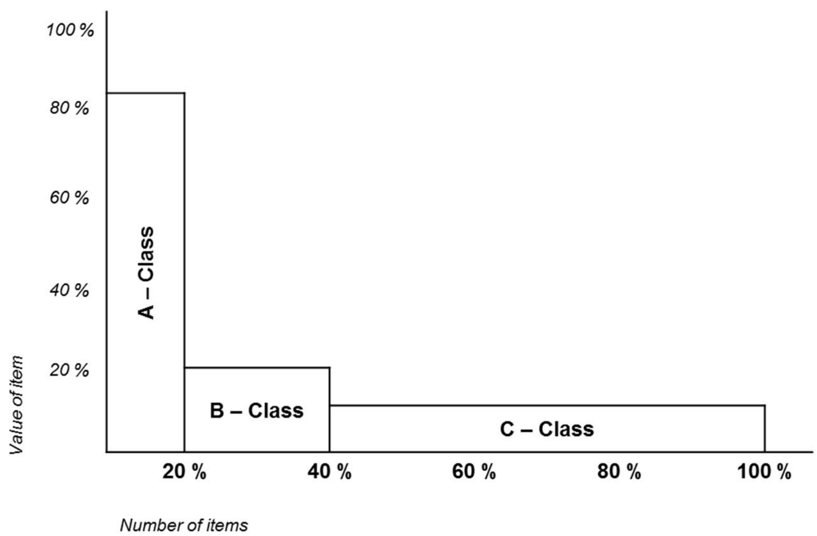


Figure 6: *ABC classification (Stevenson 2009, p. 556)*

While using this categorization, A & B – categories should receive most attention, because they are the most expensive items. On the other hand, C – items get only loose attention. Traditionally, consumption pattern classification is called the XYZ analysis. The XYZ analysis also varies which is widely preferred. For example, the XYZ analysis could be based on the frequency of demand or demand variability, whereas X-items have the largest consumption and Z-items have least consumption or irregular consumption. (Scholz-Reiter et al. 2012) There are multiple modifications of categorization, where classification can be made by some of the following (Bacchetti & Saccani 2012, p. 724):

- Demand frequency
- Part price or cost
- Demand variability
- Demand volume or value

It varies widely which classification companies prefer to use. Botter & Fortuin (2000) and Fortuin & Martin (1999) criticize single classification because expensive parts may be just cosmetic and therefore they are not critical for the machines. Also some cheap parts can be extremely critical and therefore they need to be stored with extra care. Therefore, qualitative methods are also used.

2.7.2 Qualitative methods

Items can be categorized by qualitative methods as well. Braglia et al. (2004) identifies multiple aspects for how items can be evaluated, such as:

- Obsolescence
- Number of identical parts in the system
- Frequency of failure
- Lead time
- Safety aspects
- Number of potential suppliers
- Space required
- Repair time

A widely used qualitative method is the simplified VED approach. In this type of categorization, items are categorized by its criticality and there are three different types of service parts and all describe the level of loss in cases of stock outs: vital parts cause high losses, essential parts cause moderate losses, and desirable parts cause minor losses. (Botter & Fortuin 2000, p. 662; Huiskonen 2001, p. 129)

Another qualitative method is categorizing parts by their availability or specificity. In this method, parts can be divided into three different groups: commercial parts, industry specific parts and key parts. Key parts or user-specific parts have a few possible suppliers. These parts could be like specific machine framework structure or a circuit board for specific application. Industry specific parts have the same characteristics as key parts, but they are easier to manufacture. Therefore, they have more vendors than key parts, but still they are manufactured by specific drawing or specifications. Commercial parts are common bulk materials like bolts and light bulbs which can be purchased from almost any hardware store around the world. (Paakki et al. 2011; Huiskonen 2001)

Qualitative methods are based on the consultation with maintenance experts, product development and quality control staff. Therefore, qualitative categorization may be difficult because people evaluate spare parts importance subjectively. Furthermore, quantitative analysis is more preferred in systems which include tens of thousands of items. Another argument against a qualitative approach is that different customers require different levels of service and they need to be handled in different ways. Therefore, an item's criticality may differ. (Roda et al. 2014, p. 533; Botter & Fortuin 2000)

2.7.3 Multi-criterion methods

It is widely discussed that traditional single criterion categories are not enough in complex systems, and therefore multi-criterion systems have been developed. (Syntetos et al. 2009; Roda et al. 2014) It is common that two or more criteria are combined to a multi-criterion system. Multi-criterion classification is implemented through commonly used software and ERP tools like SAP (van Kampen et al. 2012). Furthermore, in Bacchatti's (2012) researched papers, he/she proposes multi-criterion classification methods specifically for global spare part business.

Botter & Fortuin (2000) have developed a framework in which three dimensional aspects are considered: consumption, response time to a customer, and a price. These are divided into two general classes. This way managers will get 8 different item categories which are manageable. This framework is illustrated in Figure 7.

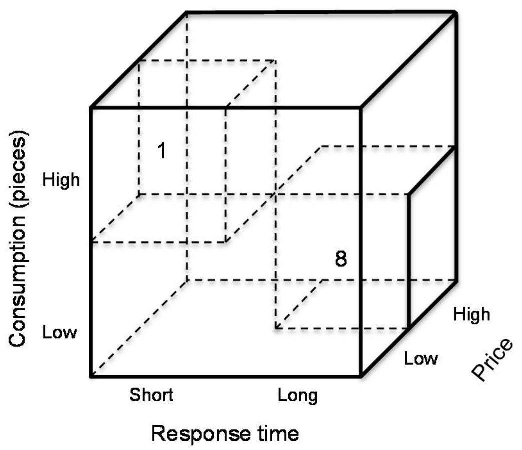


Figure 7: *Framework for consumption, response time and price variables (Botter & Fortuin 2000)*

Within this framework, each segment represents a particular group of service parts, and each with its own approach. These approaches are represented in Table 2.

Table 2: *Location decisions for different type parts (adopted from Botter & Fortuin 2000)*

Segment	Price	Response time	Usage	Storage location
1	Low	Short	High	Close to market, local warehouses
2	Low	Short	Low	Close to market, local warehouse but lower quantities than segment 1
3	Low	Long	High	Investigate inventory costs & transportation and decide
4	Low	Long	Low	Only centrally
5	High	Short	High	Primarily in local warehouses, quantities low as possible. Depending desired service level
6	High	Short	Low	Depends the price and transportation costs. Either locally or centrally. Managers decision
7	High	Long	High	Locally or centrally.
8	High	Long	Low	Stocked centrally

The framework suggests that items which have a short response time and a cheap price should be stocked near the customer. On the other hand, high value and low usage items should be stocked only centrally. There are multiple segments which need to be evaluated. Therefore, qualitative analysis could be used. Moreover, there are multiple challenges to implement this framework. It is challenging to make decisions between categorizations because there are only two categories in each dimension. If there were more dimensions, different categories would be multiplied and therefore would be difficult to handle.

Another approach to determine item categories is to define different groups by a price and demand. Paakki et al. (2011, p. 168) framework have seven different groups depending on items' demand and its variability, and material price. These categories are illustrated in Figure 8. Group 1 includes parts that did not have any transactions in two years. These should be scrapped or if they have global transactions, they should be stored to the central warehouse. The criticality of the part is related to the consequences if the part is not available. The impact of a shortage may cost more than its commercial value. If the item is marked as critical for a certain customer, the item needs to be stocked in a local warehouse even if it has no regular demand. (Paakki et al. 2011)

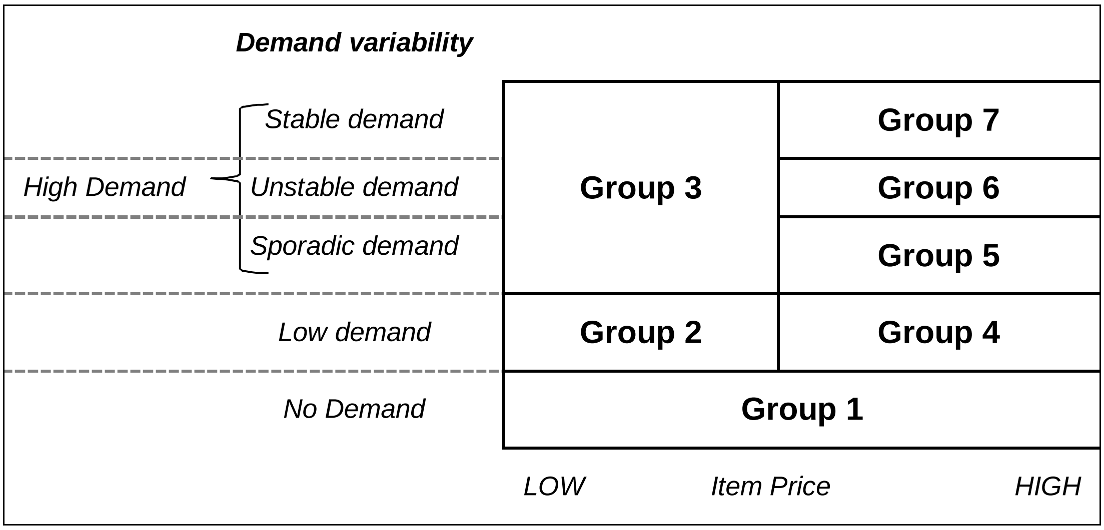


Figure 8: *Demand categorization (Paakki et al. 2011)*

Items in Group 2 & 3 have a low value; management should focus on high value groups. Groups 4-7 are the most critical because of the high price. The stable demand group 7 can be handled by standard control methods which according the point of view of management, is the best category. Group 4 is rather easy to handle because the demand is low but stable. However, this group could have a large obsolescence risk. Group 5 is the most challenging group because of the sporadic and lumpy demand. These parts should be investigated more along with checking customers' purchasing policies. Moreover, group 5 has unstable but continuous demand. Therefore, items with unstable demand should be focused on more clearly to achieve more stable demand.

When the categorization is done, management could take a closer look at items' behavior and investigate how different category items contribute to inventory performance. Each segment should have a different service level target, because it can bring benefits for cost reduction and service levels. (Huiskonen 2001; Rego & Mesquita 2015; Syntetos et al. 2009) The framework excludes one important factor: response time to the customer. If we add the response time to this framework, it becomes difficult to handle, because there would be a number of different item categories.

Management should concentrate only the parts that really matter and control the rest by means of simple rules. Hence, expensive items which have a high demand need the most attention and therefore they need to be stored in a local warehouse. In addition, some expensive parts may be for cosmetic use. If they fail, they will not have immediate influences on the machine's operations and therefore it needs to be decided if management wants to keep these items in inventory. Moreover, the cheapest parts should be stocked locally because even though they are cheap, they might cause machine breakdowns for the customer. (Botter & Fortuin 2000; Ballard 1996) Nevertheless, relying only on historical data when forecasting future demand patterns could jeopardize customer service, because some items need to be on hand even if they do not statistically have enough movement.

2.8 Forecasting in spare parts business

In literature, there are dozens of forecasting methods which have been tested in the context of spare parts in recent years. In general, demand forecasting can be divided in three different groups: judgmental, time series, and cause and effect. (Christopher 2005, p. 133). As Bacchetti (2012) mentions, time series demand forecasting such as moving average or single exponential smoothing are still the most used in practice, despite the evidence that they will overestimate the mean level of intermittent demand. Normally forecasting methods are compared by Mean Square Error (MSE) or by Mean Absolute Percentage Error (MAPE) to select the most suitable forecasting method. (Rego & Mesquita 2015; Muckstadt & Sapra 2010)

Moreover, high moving and smooth demand may not require ad hoc forecasting methods, because regular time series demand that forecasts perform accurately with smooth demand. In recent years, intermittent or lumpy demand items have been the object of forecasting in research papers. Croston's method is a widely tested forecasting method in which lumpy demand is forecasted through single exponential smoothing, the interval between demand arrivals and the demand size. Some of studies show that Croston's method and its variants are performing better than traditional time series methods. However, Syntetos & Boylan (2001) overrule Croston's method and developed an adjusted method which fits better. Nevertheless, both Croston's method and adjusted Croston's was demonstrated to be biased as well (Levén & Segerstedt 2004).

Kalchschmidt et al. (2003) suggest that forecasting should be done according to either regular or irregular demand patterns, each using different forecasting methods. If peaky demand is forecasted by a single forecasting method, demand peaks will generate distortion and unnecessary high inventory levels. In addition, huge orders reduce item availability which lowers customer satisfaction and service levels because smaller orders cannot be fulfilled. (Kalchschmidt et al. 2003) To avoid this irregular demand, information should be gathered from the largest customers. The future forecasting and planning could get useful information from large orders when the information is shared. With this action, the service company can handle the irregular demand differently than regular demand pattern. Kalchschmidt et al. (2003) found out that this framework where additional information is gathered from a small number of the biggest customers will reduce inventory levels and the service levels will stay the same. However, improvements in the logistics processes are relevant issues, but it in this thesis, it is excluded.

As Bacchetti (2012) says: *"There is still no conclusive and practitioner-oriented indication on which is "the best" forecasting method for spare parts"*. This is mainly because industry-related factors have not been part of the academic literature. Furthermore, different metrics in different studies encumbers the comparison. (Bacchetti & Saccani 2012)

2.9 KPIs in spare part management

Spare parts management should consider their inventories by simple key performance indicators (KPIs) (Paakki et al. 2011; Kalchschmidt et al. 2003). In multi-item inventories, it is inefficient to measure the service level for each item separately. Therefore, it is reasonable to calculate KPIs for item groups. (Ronen 1983) When using same KPIs, management can compare different item categories and warehouse performances over a period of time and use internal benchmarking to improve the multi-echelon inventory as a whole. As discussed in Chapter 2.7, the most demanded items need to be investigated first. Chae (2009) recommends that less is more. Companies should start with the small number of KPIs which are absolutely necessary and which the company can successfully manage and operate.

While using certain KPIs, management can find the pitfall items, because metrics will reveal the gap between a plan and execution (Chae 2009, p. 425). Although, the customer only cares about service management if the parts are not available or if they are too expensive – the only metrics that matter to the customer is machine uptime rates. (Muckstadt & Sapra 2010) Therefore, inventory targets should be the result of the policy, not the basis for policy. Altay & Litteral (2011, p. 299) recommends that KPI’s are used for analysing the following:

1. What levels of service are required and what is the current performance?
2. If service level is below the targets, fix it first before reducing costs.
3. Identify cost saving opportunities and rank them by value

Chae (2009, p. 424) recommends in his work that different supply chain operations can be divided in four different groups in production: planning, sourcing, production and delivery. By adopting this to spare part business, the proposed KPIs are illustrated in Figure 9.

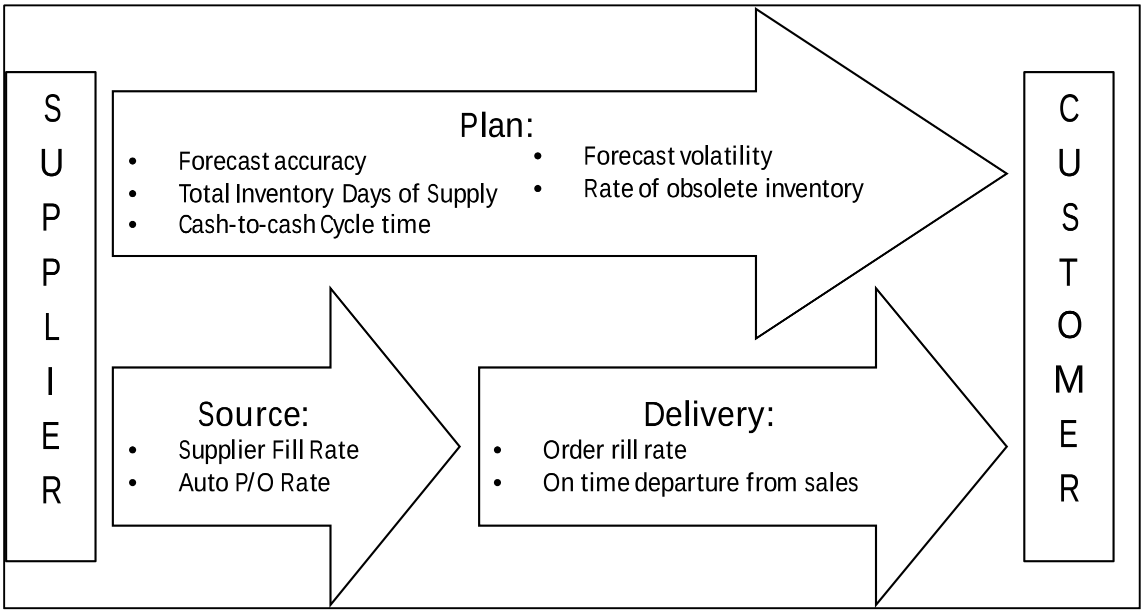


Figure 9: *Different KPIs in supply chain (Adapted from Chae 2009, p. 425)*

Typically, literature classifies KPIs in three different groups: strategic, tactical and operational, but it proves easier to divide them into primary and secondary metrics. By this categorization, top management can regularly monitor the performance by primary KPIs and secondary KPIs can give additional information to performance. (Chae 2009) The next paragraphs define the illustrated KPIs.

Primary - Forecast accuracy: It is valuable to know how forecasting methods are performing compared with actual sales or demand. Especially in the spare part business, inventory planning relies on forecast data which comes either from historical data or from sales units. Forecast accuracy can be tested mathematically, for example by MSE or MAPE. (Chae 2009; Altay & Litteral 2011, p. 67)

Primary – Total inventory days of supply (TIDS): Inventory turnover is easy to use because few parameters are needed and it shows which inventoried categories are moving fast and what need to improve. (Stevenson 2009, p. 553) Spare part inventory management cannot increase the sales significantly, therefore the only way to achieve targeted turnover is to lower the average inventory. If the turnover number is low, it indicates that there is a problem holding items in stock without sales. Therefore, every item category should be investigated by inventory turnover. Inventory turnover can be calculated by total inventory days of supply as well as which simply inverses the turnover and all multiplied by 365. The KPI will show how many days the company's inventory has left until it is depleted. TIDS is calculated by formula:

$$Total\ inventory\ days\ of\ supply\ (TIDS) = \frac{Average\ Inventory}{Cost\ of\ Goods\ Sold\ (COGS)} \times 365$$

Traditionally, TIDS is calculated once a year, but now the monthly TIDS is very desirable (Chae 2009, p. 423). In spare part inventory, monthly TIDS is also desirable because inventory levels could fluctuate because the characteristics of spare parts business.

Primary – Cash-to-cash cycle time (CCCT) measures the financial efficiency of a supply chain. CCCT measures time how long does it takes to recover its financial investment for purchasing; the shorter the CCCT, the more working capital is available. (Chae 2009, p. 425)

Secondary – Forecast volatility: A high magnitude in the forecasting makes planning very difficult. Thus, forecast volatility needs to be as low as possible for the stability of the supply chain. (Chae 2009, p. 425) As mentioned before, volatility in spare part business is one of the main reasons for high inventory levels. Forecast volatility gives additional information to forecast accuracy.

Secondary – Rate of obsolete inventory: It is important to measure an obsolete inventory at each inventory level. The obsolete inventory refers to those items which have been in the warehouse for more than a certain period, normally a year or more. These slow moving items or excess inventory means unnecessary inventory levels and high carrying costs.

Primary – Supplier fill rate: This metric measures supplier's reliability. For the proper evaluation of this metric, two considerations need to be made. First, it needs to be measured item-by-item because purchase orders normally contain more than one line. Therefore, it needs to be measured as all the requested items delivered. Secondly, the delivery date needs to be compared with the requested delivery date. If the actual delivery is too early or later than the requested delivery date, it will lower the supplier fill rate (Chae 2009, p. 426)

Secondary – Rate of automatic PO release: Today material requirement planning (MRP) is computer based and really complex. In production, automatic PO releases in raw materials are a good indicator of how streamlined the supply chain is. (Chae 2009, p. 426). Spare parts could use automatic PO releases as an example for cheap and regularly demanded parts.

Primary – Order fill rate (OFR): Teunter et al. (2010) defines Order Fill Ratio (OFR) by how many orders are completed straight from stock divided by total orders. Each order line is individually observed and if the order line is fulfilled within a given time frame, the order line is considered a "hit". (Syntetos et al. 2009, p. 299)

Christopher (2005, p. 42) defines the perfect order in which each order should be on-time, in-full and error-free. With this action, the company could define the perfect order. This is the way company could measure its customer satisfaction. Another commonly used performance measurement is OTIF, on time in full, which is the same as the perfect order, but errors are excluded from this measurement.

Primary – On time departure from sales: Chae (2009) defines this as an important indicator because normally it is difficult to figure out an actual time of arrival to the end customer. Therefore, the 2nd echelon needs to measure how often their items are shipped on time.

2.10 Conclusion of theoretical background

In previous chapters, this thesis discussed various spare part inventory management characteristics. The most critical issue is to define item categorization as most suitable for the company in question. Secondly, forecast methods need to be defined according to different categorizations. When these actions are taken, proper KPIs should be targeted to different warehouses and item categorizations. All warehouses should be measured by the same KPIs so management could compare different warehouse performances. In multi echelon systems, these need to be handled as a whole, because sub-optimization does not improve the system as a whole. The steps for improving are gathered in Table 3. The table also includes methods used in this thesis. As a concluding disclaimer, there are multiple restrictions in this thesis, and therefore all the actions cannot be evaluated.

Table 3: *Process for improving inventory management*

Step	Actions	Method used in this thesis
Item categorization	· Define different categories · Make stocking strategy decisions · Concentrate most critical/fast moving items	· Multi criterion XYZ-ABC
Demand forecasting	· Define different forecast methods for different categories · Get information from biggest customers & lower echelons to counteract against demand fluctuation · Continually decrease demand fluctuation	· Based on firm policy
KPI's	· Define different KPI targets for different item categories · Define what is the most important measurements	· TIDS · Service performance · Inventory value · Order fill rate (OFR)
Performance measurement	· Evaluate different warehouses with same KPIs · When most critical items are evaluated, move less important items	· Targeted KPIs vs. current KPIs

Through a theoretical perspective, demand forecasting should be done by adhering to simple rules and different item groups should be forecasted by different methods. In addition, information from the biggest customers should be gathered to lower demand fluctuation. Because of IT, ERP systems include complex forecasting systems which help management. On the other hand, management could have problems understanding the forecast which cause further misunderstandings or incorrect assumptions.

After that, KPI targets should be set and actions taken to achieve them. Therefore, it is necessary to implement actions to check the rock bottom items in the most critical categories and find the root causes of the problems. When the most critical parts are evaluated, move less critical items. When these actions are taken, it is recommended to evaluate the new situation and continuously improve the system as a whole. The KPIs' relevancy is important to evaluate occasionally because of the risk of sub-optimization.

3. INVENTORY MANAGEMENT & LOGISTICS AT CASE COMPANY

3.1 Supply chain and delivery processes

The Case Company's Services supply chain in EMEA region includes five levels which are suppliers, central operations, front line units, site and repair vans and customers. As discussed earlier in Chapter 2.4, the supply chain can be seen as a three echelon spare part inventory which contains distribution centers, second echelon sales offices and customer site warehouses and maintenance vans. A simplified supply chain of the Case Company's services is illustrated in Figure 10.

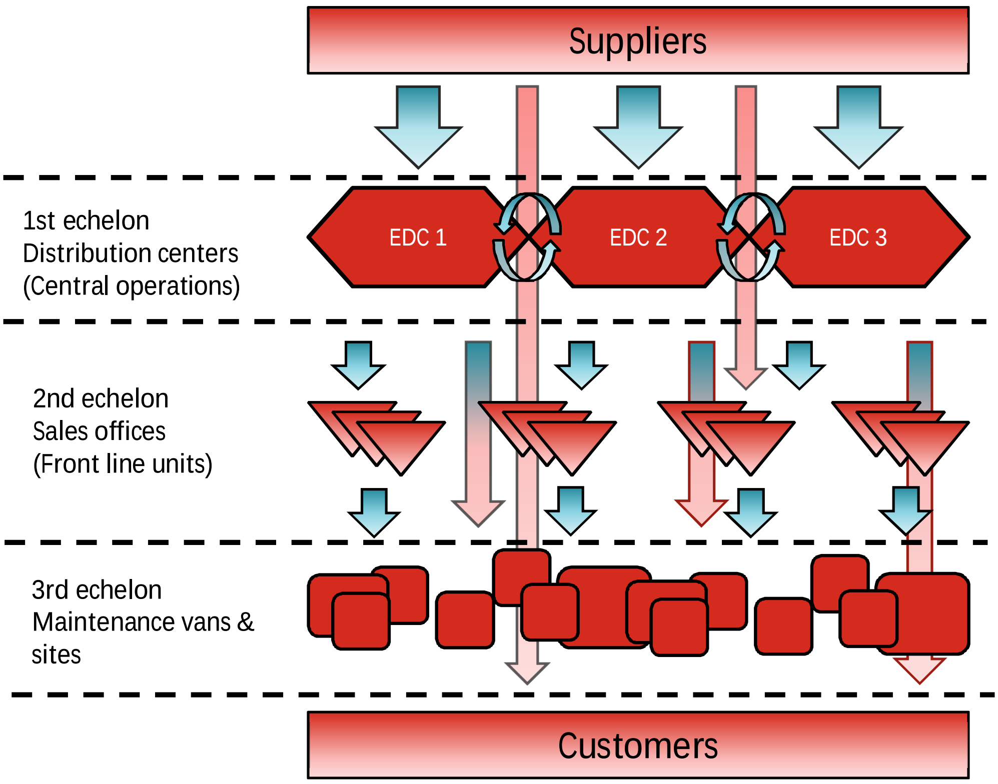


Figure 10: *Supply chain in EMEA region*

In EMEA area, the Company has three distribution centers and 15 sales offices and hundreds of rd3rd echelon maintenance vans and customer site warehouses. The Company's Services has currently around -- active suppliers and most of the deliveries are delivered to distribution centers. In a normal part delivery process, items are received at DCs. When shipment arrives to the DC, the item condition and quantity is inspected, they are inserted into specific storage location and then the received amount is logged in the ERP system. This phase may include repackaging to the Company's branded packages. In case of pending orders, cross-docking is used and the item goes straight to an outbound process instead of a physical storage location. In a normal part delivery outbound process, needed parts are collected from the inventory and then packaged and shipped to the consignee who supplies them to front line units or to the customer.

There are also multiple special processes to shorten the delivery time in urgent situations. Special items, such as large frame components may be delivered straight from the supplier to the sales offices or even straight to the customer. Sales offices can order items straight from vendors or they can also use local suppliers in case a part is not available at the DC and/or if the price is competitive.

This research focuses only on internal operations and therefore only examines the biggest distribution center in Europe, the three front line units in central Europe and their rd3rd echelons are taken into account. These three front lines units have been selected because they a have larger customer base than other EMEA FLUs and a larger volume than any other front line unit in Europe. The company has bigger FLUs outside of Europe, but this thesis concentrates only on the EMEA area.

3.2 Item classification & KPI targets

The Case Company's spare parts have tens of thousands globally active items open in the system. Therefore, item classification is needed to handle the huge amount of items. The company uses a multi-method XYZ- and ABC- classification method in their inventory management. XYZ-classification is divided into five groups X, Y, Z1, Z2 and N, depending on the sales transactions in past 12 months. Items in Class X include all the items which have more than 50 sales transactions in past 12 months. Y items include items which have 12-49 transactions in past year. Z –items are divided in two groups; Z1 (1-5 transactions) and Z2 (6-11 transactions). The last category, N -items have no transactions within the same time interval. ABC-classification refers to the cost of goods sold volume. Items in A-class generate 80% of the cost of goods sold. Furthermore, B-class items bring the next 15-% and C-class the remaining 5-%. As mentioned in the literature review, the parameters are the same as what the researchers have found most commonly used in practice. However, the Case Company does not include demand fluctuation or lead time as part of their item classification, which are areas where the literature has been focused on in recent years. (Bacchetti & Saccani 2012)

The Case Company uses multiple performance KPIs. In sourcing, the most common KPIs are delivery accuracy and a price index. These are common to evaluate supplier performance over a certain amount of time and these are also known in literature. Because this thesis is concentrating on internal processes only, these KPIs are excluded from this thesis.

In the delivery processes, the company uses mostly four different KPIs, which include 72-hour availability, 24-hour availability, "first pick" percentage and obsolescence. Both the 24- and 72-hour availabilities refer to how many order lines they could send within 24 or 72 hours when the order is placed. These will monitor how the internal processes work. In general, 72-hour availability is more used than 24-hour availability because the company has decided that sending items within 72 hours is acceptable for their business. "Availability" KPI is by concept close to the academically noticed on time departure from sales KPI. This is used because the company could not track the actual arrival time to the customer.

Secondly, they use "first pick" -rates. First pick refers to if at least one piece of the requested items is available when the order is received. This is monitored because management considers that service parts are usually ordered through critical need and it would be valuable to the customer if they receive at least one piece of a needed item immediately. First pick rates are not known in academic literature but it is important indicator for management. It will give describable information of inventory planning success. It is questionable if this indicator is relevant to overall performance and customer satisfaction. From the customers' perspective, it would be more valuable to monitor an order fill rate (OFR).

Through a planning perspective, the Case Company uses TIDS - total inventory days of supply, which refers to inventory turnover in days. Moreover, they also use the obsolescence rate to monitor their excess stock over time. As mentioned, the Case Company uses different KPIs to monitor their logistics as a whole; these KPIs are different by name but are comparable to those found in literature. In Table 4 is listed the current KPI targets which are evaluated in this thesis.

Table 4: *Current KPI targets in Case Company*

	X, Y –items target	**Total target**
Availability 72h	-- %	-- %
First pick %	-- %	Not defined
TIDS	Not Defined	-- days

The Case Company has targeted the mathematical service level for each category separately for different front line units. The planning parameters are illustrated in Figure 11. These parameters are set in the 3rdrd party software which is presented in the next chapter.

Transactions (12 months)	**Class (XYZ)**				
1-5	**Z2**	50 %	50 %	50 %	
6-11	**Z1**	55 %	77 %	88 %	
12-49	**Y**	93 %	93 %	95 %	
>= 50	**X**	94 %	94 %	95 %	
		A	**B**	**C**	**Class (ABC)**

Figure 11: *Example of mathematical service levels for different item categories in front line units.*

As the above figure shows, the planning parameters are following academic literature in that front line units concentrate on high moving items. If the total 72-hour availability KPI target for high moving items is set to 96% and their mathematical service level target is 94% - 95%, it is questionable that whether or not the mathematical satisfaction parameters are correct, even though, they do not exactly mean the same thing.

Company services are using item criticality as well. Front line sales offices can define some parts as critical. These critical parts are automatically stocked either in the frontline or the distribution center depending on their activity. This is crucial because anyone can mark parts as critical, which management sees as problematic. Since there is no framework within management for defining parts as critical in front line units, this could cause unnecessary costs.

3.3 Stocking decisions

The Case Company is using a batch perpetual inventory system, where inventory transactions are collected automatically once a day (Stevenson 2009, p. 554). The Case Company has implemented an ERP system, SAP 6.0 in late 2013. SAP sends item data and inbound/outbound transactions to a third party software called PTC Servigistics. Servigistics calculates daily inventory data and defines control parameters such as re-order points, maximum stock and economic order quantities and update them to SAP Material Master (MM) module. The module controls how spare parts are managed in purchasing planning. Purchase orders come from minimum-maximum (s, S-1) principles and they are adapted to all items. (Muckstadt & Sapra 2010, p. 185) Data transferring is illustrated in Figure 12.

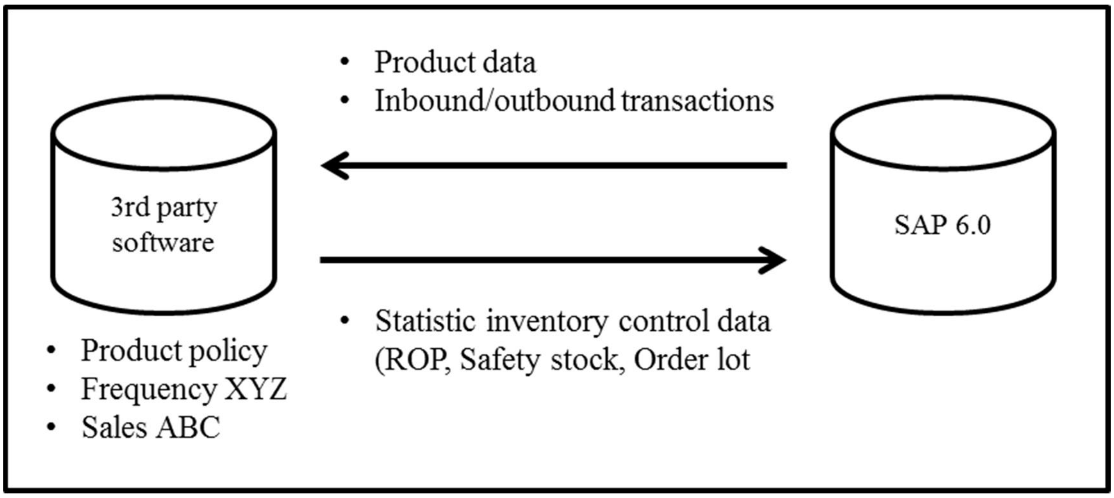


Figure 12: *Data flow between 3rd party software and SAP*

For example, every stock keeping unit has a defined minimum stock size, also called the safety stock. When the actual inventory is equal or below the minimum, the purchase order is generated to fill the stock back to its defined maximum stock. The Case Company does not use a separate safety stock amount for SKUs in the ERP system, because minimum and maximum stocks are defined by PTC Servigistics using a defined lead time and historical demand, therefore safety stock is seen as the minimum stock. With this, the Servigistics calculates every item economic order quantity automatically and when the order needs to be placed before the stock is below zero. PTC Servigistics use the following forecasting methods:

- Overall average
- 12 month moving average
- 6 or 12 month weighted moving average
- Single exponential smoothing

Servigistics calculates which forecast method has been the most accurate in history based on MAPE calculations. These forecasting methods are generally the same as the ones researchers have found in practice even though these could make overestimates especially for low-moving items. In addition, the planning team can change planning parameters manually for individual items in cases of upcoming larger orders or if the item is new and there are no historical demand data.

The company’s inventory stocking policy for front line units is illustrated in Figure 13. If an item has no local transactions in past 12 months, the item becomes locally inactive. These local inactive items should be investigated. If an item is globally inactive, has an insufficient item code/details and its price is lower than ten euros, then it should be kept in stock and attempts should be made to sell it. All globally active items in which the price is more than ten euros should be sent back to the DC. An item which has no global transactions within past five years should be scrapped.

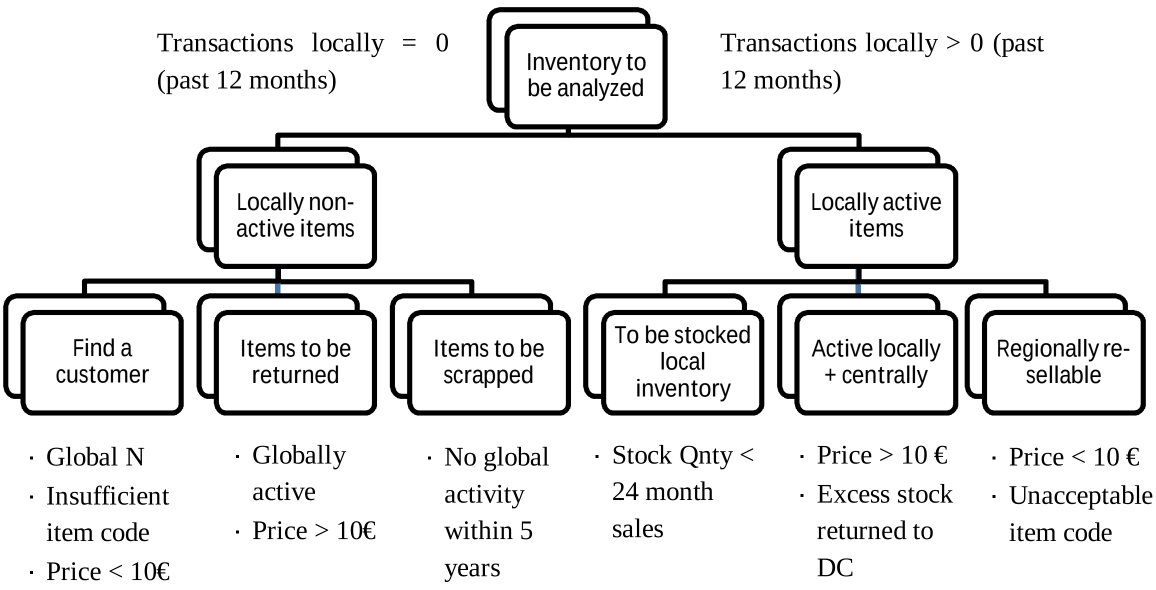


Figure 13: *Case Company stocking decisions*

On the other hand, if an item has at least one transaction in the past year, the item is locally active. These items are also divided into three different sub-groups. If the item inventory is smaller than its 24 month sales, the item should be kept in stock. Items, in which price is larger than 10 euros are kept in the stock normally, but if the stock level is larger than the past 24 month transactions, the excess stock needs to be returned to the central warehouse. The last category includes items which have local item code or it is not open for central. These items should be stored and sold regionally.

Moreover, the Company decided that if an item has less than six transactions per year, the item is then only stocked in FLU warehouse by FLU request. In this lies a conflict with mathematical service levels. The mathematical service level for low moving (Z2) items is targeted at 50%. It may lead to warehouses having excess stock in FLU warehouses.

4. DATA ANALYSIS OF CURRENT SITUATION

4.1 Data collection

The data for empirical research is gathered from the Qlikview reporting system which collects data from the SAP database once a day. Inventory values are based on a 12-month average and the data collection point is the 15th day of every month in the year of 2015. Inventory data is filled with items which have transactions, but they have not been in the warehouse during times of data collection.

The transaction data is also gathered from the reporting system and the analysis includes transactions which have been carried out during the year of 2015. The transaction data includes every transaction such as write-offs, returns to central, or storage location transactions between echelons which are not actual sales. Therefore, service usage and direct sales are only taken into account. This is crucial, because availability calculations exclude service contract deliveries. Furthermore, availability reports include direct sales orders from the DC to the customer. These figures are not in the transaction data because the items have never been in the front line unit warehouse.

The Case Company calculates its inventory value as the moving average price (MAP) by each item. The moving average price includes the following costs:

- Procurement order costs: -- € per order
- Replenishment order costs (if needed): -- € per order
- Carrying costs --% of item purchase price per item

These costs are divided into the purchase of every single item and included in the moving average price. Therefore, a single item price can be calculated by dividing inventory quantity by its value. If the item has not been in the warehouse, the price is gathered from transaction data. Data is filtered by the following rules: if the item has not been in the warehouse in the past 12 months and if it has no transactions in the same time period, the item is then excluded from calculations.

Servigistics planning tool gives a local XYZ and ABC indicator only if an item has been in the 2nd echelon warehouse. Therefore, if the item is ordered directly to rd3rd echelon or to the customer, PTC Servigistics does not give the local indicators. Furthermore, SAP does not record local indicators. Therefore, it is reasonable to recalculate indicators. ABC –calculations are based on 80%-15%-5% -method of total COGS. Additionally X, Y, Z1, Z2, N –calculations are based on the same rules as illustrated in Figure 11 and these categories are added to the availability report.

Availability is calculated by the sales order line. There are three types of availability calculations; the order line is sent to the customer within 24 hours or 72 hours. If the order line is fulfilled within the time frame, its availability is 100%, otherwise the line availability is marked as 0%. Furthermore, availability calculations includes the order fill rate calculations (first pick). It will mark first pick rate per order line either as 100% or 0% if there is at least one item available when the customer order is placed. Table 5 shows what data different files include.

Table 5: *Data to be collected*

Inventory data	Transaction data	Availability report	First pick report
· Warehouse · Material code · Material description · Stock Qnty · Stock Value	· Warehouse · Material code · Movement type · Movement volume (units) · Movement date · Movement value á · Value, movement	· Warehouse · Material code · Backorder lines (+1d) · Not in backorder lines (+1d) · Backorder (+3 d) · Not in backorder (+3 d)	· Warehouse · Material code · Available rows · Not available rows · Direct delivery Y/N · Default Vendor

The availability report does not include service contract transactions and therefore it needs to be recognized that the availability report includes less transactions than there actually are. Furthermore, the availability report includes direct deliveries from the 1st echelon (DC) to the customer and therefore these transactions are not recorded as storage movements. Moreover, the availability report checks only if the whole row is sent within the given timeframe whereas the transaction data includes all movements if the row is sent in two or more deliveries. Hence, the number of lines between the transaction data and the availability reports differs, which certainly has an effect on data analysis validity. In addition, the availability reports include freights, which are to be excluded from future calculation.

After the data collection is made, the inventory data and transaction data is combined by plant. Combined data is filled with Global XYZ and ABC –indicators directly from SAP. The same activities are carried out for the availability and first pick reports which are also combined. The availability and transaction data also includes default vendors. In this research, vendors have been divided into either the distribution center or external vendors. Because oaf this, we can analyze how the distribution center is performing against external vendors. After data is gathered and filtered, it is saved into Excel format. The data analysis is performed by using the Excel Pivot tool.

At this stage, one important factor needs to be noticed. The company calculates all invoiced actions into its TIDS calculations such as invoiced working hours and kilometer allowances as the costs of goods sold. Therefore, calculations in this thesis differ highly from management targets. A notable aspect is that warehouse FLU2 does not use Servigistics, and therefore it would be interesting to evaluate how FLU2 performs in comparison with the other two front lines.

4.2 Current levels by the first glance

The year of 2015's overall situation is illustrated in Table 6. The average inventory value for FLUs is -- million and total COGS is -- million. Resulting 187 total inventory days of supply while the targeted TIDS is 60 days by the year of 2018. The FLUs' average inventory value varies from -- to -- million. FLU1 is the largest front line unit with -- million costs of goods sold and it also has the biggest stock value with -- million. On the other hand, FLU2 has the most delivered lines and they use the most direct deliveries straight from the DC.

Table 6: *Overall situation per front line unit*

	FLU1	FLU2	FLU3	Total
Open items	--	--	--	**--**
Sales orders (601)	--	--	--	--
Service contract orders (261)	--	--	--	--
Total transactions	**--**	**--**	**--**	**--**
Avg. Stock Value	--	--	--	**--**
%	43,7 %	29,8 %	26,4 %	100,0%
COGS	--	--	--	**--**
%	39,8 %	33,9 %	26,3 %	100,0 %
TIDS	205	164	188	**187**
Direct Deliveries from DC	--	--	--	**--**
Deliveries from FLU	--	--	--	**--**
Availability report delivered lines	**--**	**--**	**--**	**--**
Availability (+1 d)	67,3 %	83,6 %	69,0 %	**76,1 %**
Availability (+3 d)	81,3 %	88,3 %	79,9 %	**84,7 %**
First pick %	83,8 %	87,5 %	81,9 %	**85,3 %**

One important factor that needs to be noticed from the above table: availability reports include total lines of -- ordered lines, whereas total transactions are over --. This is because the availability report does not take service contract deliveries into account. Thus, it is questionable if the reporting system is accurate enough since the availability report includes only 36% of total delivered lines. Furthermore, if one order line is delivered in more than one shipment, the transactions report takes all outbound into account and the availability and first pick report takes only one delivered line into account. Therefore, there are substantial differences between the actual deliveries and the reported lines.

Front line units use general item codes and they can purchase everything with the code. Therefore, future calculations will separate the general item codes because they cause disorder in the calculations. The previously mentioned management concern about using item criticality as stocking decision-making is not actually used in front lines. Therefore, there are no data to analyze critical parts performance.

4.3 Forecasting methods in use

PTC Servigistics calculates new forecasting methods once a month based on MAPE. Currently -- items in these three front line units are under the PTC Servigistics calculations and current forecasting methods are illustrated in Table 7.

Table 7: *Forecasting methods used in Case Company*

Row Labels	Different items	%	Average CV2
12-months average	--	54,2 %	1,89
12 month weighted average *	--	35,0 %	0,89
Single Exponential Smoothing **	--	10,3 %	0,96
9 months Moving Average	--	0,25 %	1,47
Intermittence Smoothing **	--	0,22 %	9,58
Grand Total	**--**	**100,0 %**	**1,27**

**) 9 months weight factor 0.5*
***) Alpha 0.1, Beta 0.05, Phi 1.0*

As the above table shows, the 12-month average is the most used forecasting method. The second most used is weighted average while the third is single exponential smoothing. It is interesting that really simple forecasting methods are more accurate based on MAPE than more complex forecasts, such as single exponential smoothing or intermittence smoothing, thus the coefficient of variation is enormous. Huge variation in demand refers either to the characteristics of the spare part business or the inaccurate forecasting methods. As the literature review tells, the demand fluctuation needs to be reduced as much as possible. Therefore, the company should concentrate on actions as Kalchschmidt et al. (2003) recommends. Additional data from customers would be valuable if it is the way to reduce the demand fluctuation. Even if the demand fluctuation cannot be reduced by such information, the Company could be proactive and get the additional demand information to reduce possible shortages.

Forecasting methods would be valuable to research. Thus, PTC Servigistics includes Croston's method as one possibility, but because it has not been in use, the software has not calculated the forecast errors for Croston's in previous months and therefore the system does not compare current forecasting methods with Croston's. If Croston's method is taken into account, the time interval between implementation and impact takes 6 months. This is not possible in this thesis, so unfortunately Croston's method evaluation needs to be excluded from this thesis.

4.4 Availability analysis

In the following sub-chapters, the availability reports and first pick reports are analyzed by different aspects. First, the analysis is done by local categories and then by global categories. After that, local categories are analyzed by plant to find differences between the analyzed plants. Furthermore, evaluations include analyses between direct deliveries from the DC and a FLU warehouse and analyses between internal and external vendors.

4.4.1 Availability analysis by local indicators

Current availability performance is illustrated in Table 8. The overall 72-hour availability is 84.7% while the target is 92%. The high moving X-items availability is 88.2% and the Y-category is performing the best with 89.9% availability. Locally low price C- items are performing the best overall.

As Table 8 shows, locally the most active items are covering only 1.95% (-- items) of all items, but they have 14.5% of total transactions. On the other hand, Z2 is covering over 60% (-- items) of all items, and they generate 43.5% of all the order lines.

Appendix 2 demonstrates availability by plant. We can see that almost every plant availability performance is below the target in X-items. As the literature review tells, front line units should concentrate on high moving items. Actually, they are but the 72h availability and first pick percentages are not achieving their targets. The best performing warehouse by availability is currently FLU2 with 88.3% availability. The poorest performance is FLU3 with 79.9% availability. Whereas, FLU3 is the best performing warehouse in high moving items, but it has the least amount of them.

Movement categories are calculated by total transactions from the transaction data report by plant. As Table 8 shows, non-moving items are actually moving. This indicates that these parts are sold by the front line unit, but the delivery has happened straight from the distribution center and therefore transactions are not recorded for the front line units. Non-moving items have a total of -- transactions in the year of 2015. This indicates that front line units are not stocking locally moving items for some reason and use direct delivery from the DC instead.

Table 8: *Total front line unit availability by local category*

Local Category	Num. of items	% of all items	% of all order lines	Availability (+1d)	Availability (+3d)	First Pick (%)
X	**--**	**1,95 %**	**14,5 %**	**83,4 %**	**88,2 %**	**95,3 %**
A	--	1,62 %	12,9 %	84,1 %	88,9 %	95,3 %
B	--	0,29 %	1,5 %	76,7 %	82,3 %	95,2 %
C	--	0,05 %	0,1 %	88,5 %	96,2 %	96,2 %
Y	**--**	**4,51 %**	**11,8 %**	**80,2 %**	**89,9 %**	**90,3 %**
A	--	1,78 %	5,4 %	78,9 %	90,5 %	88,6 %
B	--	2,01 %	4,7 %	86,1 %	92,2 %	92,4 %
C	--	0,72 %	1,7 %	68,8 %	82,2 %	89,7 %
Z1	**--**	**6,84 %**	**11,3 %**	**76,9 %**	**87,3 %**	**85,6 %**
A	--	1,87 %	3,4 %	77,0 %	87,0 %	82,8 %
B	--	2,28 %	3,7 %	82,5 %	91,4 %	87,8 %
C	--	2,69 %	4,2 %	71,9 %	83,8 %	85,9 %
Z2	**--**	**60,81 %**	**43,5 %**	**69,8 %**	**81,5 %**	**84,0 %**
A	--	3,61 %	3,4 %	71,5 %	81,8 %	86,0 %
B	--	8,90 %	7,6 %	78,2 %	87,7 %	88,2 %
C	--	48,30 %	32,5 %	67,7 %	80,0 %	82,8 %
N	**--**	**25,87 %**	**17,5 %**	**86,2 %**	**87,9 %**	**77,5 %**
GEN	**--**	**0,02 %**	**1,4 %**	**24,3 %**	**42,4 %**	**77,7 %**
Total	**--**	**100,00 %**	**100,0 %**	**76,1 %**	**84,7 %**	**85,3 %**
No Gen	**--**	**99,98 %**	**98,6 %**	**76,8 %**	**85,3 %**	**85,4 %**

While comparing the first pick rate by order line and 72-hour availability we can see that for example, X - items' first pick percentages are better than 72-hour availability. First pick rate is generally performing better than 72h availability on moving items than low moving items. This indicates that front line units have at least some stock, but the delivery process to the customer might take too long, or there is not enough stock.

Some of the orders may be "Ship Complete" – deliveries, in which all of the items are sent together. Thus, if one or more items are missing from the order, it is not delivered until the missing items are in stock. Nevertheless, only -- sales orders are shipped as complete including a total of -- rows. Therefore, complete deliveries do not affect the overall situation.

4.4.2 Availability analysis by global indicators

If we compare availability by global indicators, we find out that the X-category covers 25.7% of all evaluated items and their 72-hour availability is 3.5% better than local indicators. With global indicators we can see that the number of items is better distributed by different categories. On the other hand, globally low moving items' availability is much lower than high moving. The reason for this is simple - the globally low moving items' service level is targeted lower than high moving items. Therefore, stockouts occur. Moreover, the DC is stocking globally moving items, and therefore they are performing better. Availability by global categories is illustrated in Table 9.

As the following table shows, there are over -- items which are marked as "N", but they still have transactions. This will show that the item categorization is either inaccurate or the item categorization update interval is low. This may explain the inaccuracy in item categorizations. On the other hand, the reporting system gives the global indicator even if it is not open globally, thereby causing distortion in calculations.

It is an important finding that the current reporting system reports availabilities only by global indicators. This is technically misleading, because it does necessarily mean that items are locally high moving. As Tables 8 and 9 show, that reporting system shows that 48% of ordered lines are from X-category, but it is actually only 14.5%.

Table 9: *Item category performance by global categories, freight excluded*

Global Category	Num. of items	% of all items	% of all order lines	Availability (+1d)	Availability (+3d)	First Pick (%)
X	**--**	**25,67 %**	**48,20 %**	**85,5 %**	**91,7 %**	**90,3 %**
A	--	13,83 %	32,24 %	84,4 %	90,7 %	90,9 %
B	--	7,10 %	10,26 %	87,2 %	93,3 %	88,1 %
C	--	4,74 %	5,70 %	88,5 %	94,4 %	90,7 %
Y	**--**	**27,13 %**	**22,83 %**	**79,1 %**	**89,5 %**	**85,8 %**
A	--	6,03 %	5,55 %	74,8 %	86,6 %	82,1 %
B	--	9,08 %	7,86 %	78,7 %	89,8 %	86,6 %
C	--	12,01 %	9,42 %	81,9 %	90,9 %	87,3 %
Z1	**--**	**22,19 %**	**13,76 %**	**66,3 %**	**77,1 %**	**78,9 %**
A	--	1,62 %	1,10 %	49,2 %	56,8 %	62,1 %
B	--	5,28 %	3,50 %	63,1 %	74,6 %	74,1 %
C	--	15,28 %	9,16 %	69,5 %	80,5 %	82,7 %
Z2	**--**	**14,29 %**	**7,35 %**	**60,5 %**	**68,4 %**	**75,7 %**
A	--	0,27 %	0,16 %	25,5 %	29,8 %	57,4 %
B	--	1,46 %	0,75 %	52,8 %	58,7 %	66,1 %
C	--	12,55 %	6,43 %	62,3 %	70,5 %	77,3 %
N	**--**	**10,71 %**	**6,45 %**	**44,8 %**	**59,2 %**	**72,7 %**
Gen	**--**	**0,02 %**	**1,41 %**	24,3 %	42,4 %	77,7 %
Total	**--**	**100,00 %**	**48,20 %**	**76,1 %**	**84,7 %**	**85,3 %**
No GEN	**--**	**-**	**-**	**76,8 %**	**85,3 %**	**85,4 %**

Even though, the Servigistics uses local indicators for defining the stock levels, the reporting system uses global indicators. Because of this, further analysis is done by calculating local categories and different evaluations are done for each plant to find differences between FLUs.

4.4.3 Availability by local and direct deliveries

In Table 10, the overall situation is illustrated by local and direct deliveries. The data is found in Appendix 4. The order lines columns refer to the percentage of the row. Furthermore, order lines under total – columns, refers to the percentage of the total row column. As we can see, X-items are mostly delivered from the local warehouse. It is interesting why almost one-fourth of X-item deliveries are delivered directly from the DC, because the FLU should have X-items in stock.

The following table illustrates that there are -- items which are marked as locally non-moving and they generate -- transactions. Almost every one of them are distributed from the DC. There are two possible explanations for this. First, locally non-moving items are extremely rare and they are therefore distributed from the DC. Second, when the categorization is calculated by warehouse transactions, the item is marked as N, because it has no outbound transaction from the front line unit warehouse.

As we can see, direct deliveries from the distribution center is performing 72-hour availability generally well, but the local deliveries decrease the total availability in every category significantly. First pick percentage is not analyzed, because it is unnecessary in evaluating direct deliveries from the distribution center.

Table 10: *72 hour availability between local and direct deliveries, all FLUs*

	From local WH		**Direct from DC**		**Total**		
Local Category	**Order Lines**	**Avail. (+3d)**	**Order Lines**	**Avail (+3d)**	**Order Lines**	**Avail. (+3d)**	**Items**
X	**76,9 %**	**86,7 %**	**23,1 %**	**93,2 %**	**14,5 %**	**88,2 %**	**--**
A	77,5 %	87,7 %	22,5 %	92,8 %	12,9 %	88,9 %	--
B	74,9 %	77,8 %	25,1 %	95,4 %	1,5 %	82,3 %	--
C	26,9 %	85,7 %	73,1 %	100,0 %	0,1 %	96,2 %	**--**
Y	**70,9 %**	**86,8 %**	**29,1 %**	**97,5 %**	**11,8 %**	**89,9 %**	**--**
A	76,7 %	88,7 %	23,3 %	96,2 %	5,4 %	90,5 %	--
B	63,1 %	88,8 %	36,9 %	98,0 %	4,7 %	92,2 %	--
C	73,9 %	76,2 %	26,1 %	99,2 %	1,7 %	82,2 %	--
Z1	**64,3 %**	**81,4 %**	**35,7 %**	**97,9 %**	**11,3 %**	**87,3 %**	**--**
A	65,2 %	81,1 %	34,8 %	98,2 %	3,4 %	87,0 %	--
B	59,1 %	87,3 %	40,9 %	97,3 %	3,7 %	91,4 %	--
C	68,1 %	77,0 %	31,9 %	98,2 %	4,2 %	83,8 %	--
Z2	**66,8 %**	**74,4 %**	**33,2 %**	**95,9 %**	**43,5 %**	**81,5 %**	**--**
A	68,0 %	76,2 %	32,0 %	93,5 %	3,4 %	81,8 %	--
B	59,3 %	81,0 %	40,7 %	97,3 %	7,6 %	87,7 %	--
C	68,4 %	72,8 %	31,6 %	95,7 %	32,5 %	80,0 %	--
N	**1,2 %**	**6,7 %**	**98,8 %**	**88,9 %**	**17,5 %**	**87,9 %**	**--**
GEN	100,0 %	42,4 %	0,0 %	-	**1,4 %**	42,4 %	--
Total	**57,4 %**	**78,4 %**	**42,6 %**	**93,1 %**	**100,0 %**	**84,7 %**	**--**
No GEN	**-**	**79,3 %**	**-**	**93,1 %**	**-**	**85,3 %**	**--**

One possible explanation for the difference between 72-hour availability can be explained by special procurement. When a direct delivery from the DC is used, the situation is extremely urgent and the special procurement are used. As we can see in this case, direct deliveries from the DC are performing well.

As the above table illustrates, it is strongly recommended that front line units should use more direct deliveries from the distribution center especially for locally low moving items, because the DC shows extensively greater performance than items which are rotating via local warehouse. However, the logistics costs are not evaluated. Thus, it would be cheaper send weekly deliveries from the DC to the front line unit rather than send the items straight to the customer. Next, the thesis evaluates 72-hour availability by different FLUs.

FLU1:

Table 11 shows that most delivered lines from FLU1 are delivered from their own stock. This can be explained in that their inventory includes a lot of globally non-open items (Appendix 3) and therefore central operations cannot deliver the items. As we can see, 72h availability from the distribution center is achieving the targets, but locally delivered lines are performing weaker in every category than the DC deliveries.

Table 11: *FLU1 availability divided by category and delivered plant.*

	Local		Direct from DC		Total		
Local Category	**Order Lines**	**Avail. (+3d)**	**Lines**	**Avail (+3d)**	**Order Lines**	**Avail. (+3d)**	**Number of items**
X	**90,7 %**	**94,0 %**	**9,3 %**	**98,6 %**	**9,1 %**	**94,4 %**	**--**
A	90,2 %	95,2 %	9,8 %	98,5 %	8,2 %	95,5 %	--
B	94,7 %	83,1 %	5,3 %	100,0 %	0,9 %	84,0 %	--
C	100,0 %	100,0 %	0,0 %	-	0,0 %	100,0 %	--
Y	**91,5 %**	**87,6 %**	**8,5 %**	**95,6 %**	**18,6 %**	**88,3 %**	**--**
A	91,3 %	89,2 %	8,7 %	93,0 %	9,6 %	89,5 %	--
B	89,5 %	95,5 %	10,5 %	98,1 %	5,8 %	95,7 %	--
C	95,7 %	70,1 %	4,3 %	100,0 %	3,2 %	71,4 %	--
Z1	**89,5 %**	**83,2 %**	**10,5 %**	**93,5 %**	**17,4 %**	**84,3 %**	**--**
A	89,1 %	87,7 %	10,9 %	97,4 %	4,2 %	88,8 %	--
B	86,1 %	90,8 %	13,9 %	94,6 %	4,7 %	91,3 %	--
C	91,7 %	77,0 %	8,3 %	90,0 %	8,5 %	78,1 %	--
Z2	**90,8 %**	**77,0 %**	**9,2 %**	**97,8 %**	**47,0 %**	**78,9 %**	**--**
A	86,7 %	88,5 %	13,3 %	96,4 %	2,5 %	89,6 %	--
B	85,4 %	89,7 %	14,6 %	98,7 %	6,3 %	91,0 %	--
C	91,9 %	74,3 %	8,1 %	97,7 %	38,2 %	76,2 %	--
N	**9,2 %**	**16,7 %**	**90,8 %**	**88,2 %**	**3,1 %**	**81,7 %**	**--**
GEN	**100,0 %**	**42,5 %**	**0,0 %**	**-**	**4,8 %**	**42,5 %**	**--**
Total	**88,6 %**	**79,7 %**	**11,4 %**	**94,5 %**	**100,0 %**	**81,3 %**	**--**
No GEN	**88,0 %**	**81,8 %**	**12,0 %**	**94,5 %**	**95,2 %**	**83,3 %**	**--**

FLU1 is performing with 94.4% 72h availability in X-items. Moreover, the balance between delivered X&Y-items from FLU/DC are close to 90%/10%, which as academic literature claims, FLUs need to concentrate on high moving items. On the other hand, X&Y items generate only 27.7% of the total order lines; this is either due to the characteristics of spare parts or the borders of XYZ – categorization need to be reconsidered.

It is interesting that 47% of all orders are Z2-items and over 90% are delivered from the front line unit. This shows that they try to keep everything in stock. FLU1 uses the general item code the most out of all the analyzed warehouses. In the availability report, the general item code decreases FLU1 72-hour availability from 83.3% to 81.3%. As Appendix 4 shows, the general item code generates 5.0 % of all transactions in FLU1. As a recommendation, the general item code usage needs to be reduced, because it causes distortion in the reports.

FLU2:

FLU2 uses the most direct deliveries from the distribution center. In its deliveries, 63.7 % are direct deliveries from the DC. And as we can see, direct deliveries are performing better in every category than locally delivered lines. Direct deliveries achieve the targets in every category. In Table 12 illustrates FLU2 delivered lines divided by the category and delivered plant.

Table 12: *FLU2 availability divided by category and delivered plant.*

Local Category	From Local WH		Direct from DC		Total		
	Order Lines	Avail. (+3d)	Order Lines	Avail. (+3d)	Order Lines	Avail. (+3d)	Items
X	**78,1 %**	**84,5 %**	**21,9 %**	**92,0 %**	**20,6 %**	**86,1 %**	**--**
A	79,0 %	85,4 %	21,0 %	91,3 %	18,3 %	86,7 %	--
B	71,5 %	75,8 %	28,5 %	95,7 %	2,2 %	81,5 %	--
C	16,7 %	0,0 %	83,3 %	100,0 %	0,0 %	83,3 %	--
Y	**50,0 %**	**84,8 %**	**50,0 %**	**98,6 %**	**8,8 %**	**91,7 %**	**--**
A	57,4 %	90,2 %	42,6 %	98,7 %	3,7 %	93,8 %	--
B	44,2 %	76,8 %	55,8 %	98,2 %	4,1 %	88,7 %	--
C	46,8 %	91,7 %	53,2 %	100,0 %	1,0 %	96,1 %	--
Z1	**32,1 %**	**78,9 %**	**67,9 %**	**98,7 %**	**8,9 %**	**92,3 %**	**--**
A	37,1 %	77,1 %	62,9 %	98,5 %	2,8 %	90,5 %	--
B	36,3 %	81,0 %	63,7 %	98,0 %	3,6 %	91,8 %	--
C	20,2 %	77,0 %	79,8 %	99,7 %	2,5 %	95,1 %	--
Z2	**36,6 %**	**69,8 %**	**63,4 %**	**96,4 %**	**35,2 %**	**86,7 %**	**--**
A	54,0 %	72,3 %	46,0 %	93,2 %	3,8 %	81,9 %	--
B	41,0 %	71,6 %	59,0 %	97,6 %	8,4 %	86,9 %	--
C	32,0 %	68,3 %	68,0 %	96,4 %	22,9 %	87,5 %	--
N	**0,5 %**	**0,0 %**	**99,5 %**	**90,2 %**	**26,6 %**	**89,8 %**	**--**
GEN	100,0 %	0,0 %	0,0 %	0,0 %	**0,0 %**	0,0 %	**--**
Total	**36,3 %**	**78,6 %**	**63,7 %**	**93,9 %**	**100,0 %**	**88,3 %**	**--**

As we can see from the table above, X- items are almost 80% distributed from the local warehouse. On the other hand, only 50% of Y- items is distributed from local the warehouse. X&Y- items generate almost 30% of all ordered lines. Moreover, the X&Y – items availability from local the WH is around 5% lower than it is at FLU1.

FLU2 uses direct deliveries from the DC sensibly in low moving items. Almost every locally non-moving item is distributed from the DC and they are performing at over 90% availability. Moreover, locally low moving items are also performing well when they are distributed directly from the DC. On the other hand, FLU2 has an extensive amount of non-moving items in their stock. This means that they do not keep items in stock which are actually moving and therefore they will send them directly from the distribution center. This can be a consequence of not using the 3rdrd party planning software and therefore these items are not automatically turning to a stock keeping unit after more than six transactions has been made during the past 12 months.

FLU2 also has the general item code, but it is not used on the same scale as in FLU1. The general item code should only be used in extremely rare cases and it should not affect the overall situation as it does in FLU1.

FLU3:

The first significant difference between FLU3 and other previous FLUs is the small amount of generated order lines in X and Y – categories. As Table 13 illustrates, these items generate only 15.8% of total orders. X & Y – items cover 6% of all items in FLU3 which is the second largest percentage of the evaluated plants. Therefore, it is questionable if the parameter setting is correct for FLU3. On the other hand, a low number of high moving item orders may indicate a difficult customer base that has a large variety of machinery and therefore requiring various spare parts.

Another significant difference is that the low moving, low value Z2-C items generate almost 50% of all orders whereas other FLUs same category items generate 23-38% of all orders. Moreover, FLU3 prefers to deliver Z2 items mostly from its own warehouse. Hence, there are similarities between FLU1 and FLU3.

FLU3 is performing the best in high moving categories, X and Y, but over 60% of these categories are distributed from the DC. Thus causing a significant increase in its availability. In contrast, most of the low moving items are distributed from local warehouses.

FLU3 does not use general codes, but still their local availability is the weakest of the analyzed site locations. The reason for this is weak performance in the low moving Z2 category. As all the availability evaluations show, FLU3 could increase its availability performance if locally low moving items are distributed by the DC.

Table 13: *FLU3 availability divided by category and delivered plant.*

Category	From local WH		Direct from DC		Total		
	Order Lines	Avail. (+3d)	Order Lines	Avail. (+3d)	Order Lines	Avail. (+3d)	Items
X	**34,8 %**	**89,9 %**	**65,2 %**	**95,1 %**	**6,2 %**	**93,3 %**	**--**
A	32,9 %	90,7 %	67,1 %	94,9 %	5,4 %	93,6 %	--
B	62,1 %	83,3 %	37,9 %	90,9 %	0,5 %	86,2 %	--
C	22,2 %	100,0 %	77,8 %	100,0 %	0,3 %	100,0 %	--
Y	**61,3 %**	**87,3 %**	**38,7 %**	**95,1 %**	**9,6 %**	**90,3 %**	**--**
A	70,6 %	83,1 %	29,4 %	89,8 %	3,7 %	85,1 %	--
B	57,2 %	90,9 %	42,8 %	97,2 %	4,6 %	93,6 %	--
C	50,0 %	89,5 %	50,0 %	97,4 %	1,4 %	93,4 %	--
Z1	**76,1 %**	**77,5 %**	**23,9 %**	**97,2 %**	**8,3 %**	**82,2 %**	**--**
A	82,8 %	71,7 %	17,2 %	97,0 %	3,5 %	76,0 %	--
B	69,8 %	87,8 %	30,2 %	94,9 %	2,4 %	89,9 %	--
C	72,6 %	77,6 %	27,4 %	100,0 %	2,5 %	83,7 %	--
Z2	**85,9 %**	**74,1 %**	**14,1 %**	**90,2 %**	**60,7 %**	**76,4 %**	**--**
A	90,3 %	70,1 %	9,7 %	94,4 %	3,4 %	72,4 %	--
B	81,7 %	83,8 %	18,3 %	93,3 %	7,5 %	85,6 %	--
C	86,2 %	73,0 %	13,8 %	89,4 %	49,9 %	75,2 %	--
N	**2,2 %**	**0,0 %**	**97,8 %**	**82,8 %**	**15,1 %**	**81,0 %**	**--**
Total	**66,9 %**	**75,7 %**	**33,1 %**	**88,5 %**	**100,0 %**	**79,9 %**	**--**

As the availability report between local and direct deliveries from the DC shows, locally low moving items availability is better straight from the DC rather than local warehouses. In addition, low moving items generates most of the order lines in every evaluated FLU. FLU3 is the only warehouse which uses the DC more in X-item category. FLU2's item sending policy is follows the academic recommendation somewhat, in that it is concentrating on high moving items locally and low moving items are distributed from the DC.

4.4.4 Availability analysis between vendors

Front line units may purchase items either internally from the European distribution center or locally by using external vendors. This is an important issue because front line units may get the parts cheaper locally or in urgent situations, the local vendor may deliver the item faster than the DC. In Table 14 the differences are analysed between externally or internally purchased items. Items and orders columns refer to the percentage of row total.

As the results illustrate, the front line most likely uses the distribution center as a default vendor. The distribution center is marked as a default vendor for 83.5% of the ordered lines and it covers over 83.1% of all items. The DC availability is better in every category excluding X-C –items. Nevertheless, X-C –category covers only 0.05% (see Table 8) of all items and therefore its validity is questionable.

Table 14: *Item categories availability and order fill rates between vendors, all plants*

Local Category	External Vendor				Distribution center			
	Items	Orders	Avail. (+3d) %	First Pick (%)	Items	Orders	Avail. (+3d) %	First Pick (%)
X	**24,2 %**	**25,7 %**	**83,3 %**	**96,1 %**	**75,8 %**	**74,3 %**	**89,9 %**	**95,0 %**
A	21,2 %	21,7 %	85,4 %	95,9 %	78,8 %	78,3 %	89,8 %	95,1 %
B	42,1 %	61,1 %	76,6 %	96,6 %	57,9 %	38,9 %	91,1 %	92,9 %
C	16,7 %	7,7 %	100,0 %	100,0 %	83,3 %	92,3 %	95,8 %	95,8 %
Y	**13,7 %**	**14,2 %**	**78,2 %**	**92,6 %**	**86,3 %**	**85,8 %**	**91,9 %**	**89,9 %**
A	12,9 %	12,0 %	88,8 %	91,5 %	87,1 %	88,0 %	90,7 %	88,2 %
B	11,8 %	11,6 %	91,7 %	99,4 %	88,2 %	88,4 %	92,2 %	91,5 %
C	21,1 %	27,9 %	48,9 %	86,5 %	79,0 %	72,1 %	95,1 %	91,0 %
Z1	**13,5 %**	**12,0 %**	**64,1 %**	**80,4 %**	**86,5 %**	**88,0 %**	**90,4 %**	**86,3 %**
A	7,8 %	6,2 %	61,7 %	58,3 %	92,2 %	93,8 %	88,7 %	84,4 %
B	14,4 %	11,3 %	86,8 %	90,1 %	85,6 %	88,7 %	92,0 %	87,6 %
C	16,7 %	17,3 %	51,9 %	81,1 %	83,3 %	82,7 %	90,5 %	86,9 %
Z2	**22,3 %**	**17,6 %**	**74,6 %**	**89,3 %**	**77,7 %**	**82,4 %**	**83,0 %**	**82,8 %**
A	23,3 %	17,6 %	63,7 %	87,1 %	76,7 %	82,4 %	85,6 %	85,7 %
B	24,8 %	17,5 %	83,4 %	90,9 %	75,2 %	82,5 %	88,6 %	87,6 %
C	21,8 %	17,6 %	73,7 %	89,1 %	78,2 %	82,4 %	81,4 %	81,4 %
N	**4,9 %**	**4,0 %**	**67,2 %**	**63,2 %**	**95,1 %**	**96,0 %**	**88,8 %**	**78,1 %**
GEN	**100,0%**	**100,0%**	42,4 %	77,7 %	**0,0 %**	**0,0 %**	-	-
Total	**16,9 %**	**16,5 %**	**73,0 %**	**88,3 %**	**83,1 %**	**83,5 %**	**89,9 %**	**84,7 %**
NO GEN	**16,8 %**	**15,3 %**	**75,9 %**	**89,3 %**	**83,2 %**	**84,7 %**	**87,0 %**	**84,7 %**

An interesting result is that the first pick rate is performing for externally purchased items on every category excluding non-moving items. On the other hand, all the liquids, such as oils and coolants are purchased externally because they are not available from the DC. Moreover, the liquids storage unit is liter and therefore there most certainly is some inventory left. Because of the first pick equation, it may increase the first pick rates for externally purchased items. Comparing first pick rates with 72-hour availability, it questions the reliability of the first pick indicator. Customers do not get any value from in stock items, if they do not get them on time.

As results show, the general item codes are marked as externally purchased and it decreases the external vendors' 72-hour availability by 2.9 percentage. For a deeper analysis of the situation, the thesis evaluates all front line units individually.

FLU1:

FLU1 most commonly uses the distribution center as a default vendor. The comparison is illustrated in Table 15. It shows that the distribution center is performing better in availability even though, it has more than 60% ordered lines than external vendors. Table 15 shows that the first pick rate is 100% for external vendors for high moving items. The reason for this may be that externally purchased items include all the fluids. Moreover, as mentioned before, the first pick rate is a questionable indicator.

Seemingly X-C category is performing extremely well, but as the Appendix 5 shows, there is only one item in that category, so the comparison is not valid. The biggest challenge in a high moving category is the X-B category, because its total availability is only 84%.

Table 15: *FLU1 availability & First Pick rates divided into external vendor and DC*

Local Category	External Vendor				Distribution center			
	Items	Orders	Avail. (+3d) %	First Pick (%)	Items	Orders	Avail. (+3d) %	First Pick (%)
X	**28,4 %**	**17,1 %**	**90,9 %**	**100,0 %**	**71,6 %**	**82,9 %**	**95,2 %**	**98,3 %**
A	21,7 %	13,1 %	94,5 %	100,0 %	78,3 %	86,9 %	95,7 %	98,3 %
B	53,8 %	52,0 %	82,1 %	100,0 %	46,2 %	48,0 %	86,1 %	97,2 %
C	100,0 %	100,0 %	100,0 %	100,0 %	0,0 %	0,0 %	-	-
Y	**19,3 %**	**17,8 %**	**67,6 %**	**90,4 %**	**80,7 %**	**82,2 %**	**92,8 %**	**89,2 %**
A	11,5 %	9,4 %	84,2 %	89,5 %	88,5 %	90,6 %	90,1 %	87,6 %
B	18,9 %	13,8 %	88,2 %	100,0 %	81,1 %	86,2 %	96,9 %	92,5 %
C	40,0 %	49,6 %	48,2 %	86,1 %	60,0 %	50,4 %	94,2 %	87,1 %
Z1	**17,2 %**	**18,4 %**	**58,6 %**	**78,8 %**	**82,8 %**	**81,6 %**	**90,1 %**	**85,1 %**
A	9,5 %	9,8 %	65,7 %	62,9 %	90,5 %	90,2 %	91,3 %	80,1 %
B	15,8 %	11,9 %	93,8 %	89,6 %	84,2 %	88,1 %	91,0 %	87,0 %
C	21,6 %	26,4 %	48,4 %	78,9 %	78,4 %	73,6 %	88,7 %	86,8 %
Z2	**21,2 %**	**20,6 %**	**67,4 %**	**86,2 %**	**78,8 %**	**79,4 %**	**81,9 %**	**78,6 %**
A	21,8 %	19,9 %	71,4 %	90,5 %	78,2 %	80,1 %	94,1 %	86,4 %
B	24,1 %	21,7 %	85,3 %	87,1 %	75,9 %	78,3 %	92,6 %	84,0 %
C	20,8 %	20,4 %	64,0 %	85,8 %	79,2 %	79,6 %	79,4 %	77,2 %
N	**3,8 %**	**3,8 %**	**40,0 %**	**80,0 %**	**96,2 %**	**96,2 %**	**83,3 %**	**68,7 %**
GEN	**100,0 %**	**100,0 %**	42,5 %	77,9 %	**0,0 %**	**0,0 %**	-	-
Total	**19,8 %**	**22,7 %**	**62,4 %**	**84,9 %**	**80,2 %**	**77,3 %**	**86,9 %**	**83,4 %**
NO GEN	**19,8 %**	**18,8 %**	**67,7 %**	**86,8 %**	**71,6 %**	**81,2 %**	**86,9 %**	**83,4 %**

FLU1 has difficulties with externally purchased items. The total 72-hour availability of externally purchased items is only 62.4% whereas items that are purchased from the DC are performing with 86.9%. More surprisingly, C-items seems to have difficulties achieving even 50% performance although C-category items should be stocked locally.

FLU2:

The same evaluation is done to FLU2 and it is illustrated in Table 16. It shows that FLU2 uses the DC as its default vendor even more than FLU1. Comparing the high moving items, results show that same regularity appears in this warehouse: the distribution center is performing better than external vendors.

Table 16: *FLU2 availability & First Pick rates divided into external vendor and DC*

Local Category	External Vendor				Distribution center			
	Items	Orders	Avail. (+3d) %	First Pick (%)	Items	Orders	Avail. (+3d) %	First Pick (%)
X	**26,0 %**	**30,3 %**	**82,0 %**	**95,6 %**	**74,0 %**	**69,7 %**	**87,9 %**	**95,1 %**
A	23,4 %	25,9 %	84,1 %	95,5 %	76,6 %	74,1 %	87,6 %	95,2 %
B	47,1 %	68,2 %	75,6 %	96,0 %	52,9 %	31,8 %	94,3 %	93,3 %
C	0,0 %	0,0 %	-	-	100,0 %	100,0 %	83,3 %	83,3 %
Y	**9,0 %**	**10,2 %**	**98,5 %**	**98,5 %**	**91,0 %**	**89,8 %**	**91,0 %**	**91,1 %**
A	12,3 %	13,1 %	98,6 %	98,6 %	87,7 %	86,9 %	93,1 %	91,0 %
B	9,3 %	10,3 %	98,4 %	98,4 %	90,7 %	89,7 %	87,6 %	91,1 %
C	0,0 %	0,0 %	-	-	100,0 %	100,0 %	96,1 %	91,6 %
Z1	**7,1 %**	**4,5 %**	**85,0 %**	**96,7 %**	**92,9 %**	**95,5 %**	**92,7 %**	**88,8 %**
A	2,6 %	0,7 %	100,0 %	100,0 %	97,4 %	99,3 %	90,5 %	90,5 %
B	11,7 %	8,8 %	87,2 %	95,7 %	88,3 %	91,2 %	92,2 %	88,2 %
C	5,6 %	2,7 %	70,0 %	100,0 %	94,4 %	97,3 %	95,8 %	87,7 %
Z2	**13,1 %**	**8,5 %**	**67,7 %**	**90,6 %**	**86,9 %**	**91,5 %**	**88,5 %**	**88,1 %**
A	14,7 %	10,6 %	57,4 %	85,2 %	85,3 %	89,4 %	84,8 %	86,5 %
B	12,8 %	8,4 %	72,6 %	94,3 %	87,2 %	91,6 %	88,2 %	89,2 %
C	12,9 %	8,2 %	68,1 %	90,4 %	87,1 %	91,8 %	89,2 %	88,0 %
N	**3,9 %**	**3,2 %**	**70,1 %**	**60,6 %**	**96,1 %**	**96,8 %**	**90,4 %**	**78,9 %**
GEN	**100,0%**	**100,0%**	0,0 %	0,0 %	**0,0 %**	**0,0 %**	-	-
Total	**8,9 %**	**11,4 %**	**78,7 %**	**91,9 %**	**91,1 %**	**88,6 %**	**89,6 %**	**86,9 %**
NO GEN	**8,9 %**	**11,4 %**	**78,7 %**	**91,9 %**	**91,1 %**	**88,6 %**	**89,6 %**	**86,9 %**

FLU2 has only -- items in a C-X category and therefore it is not comparable. Y –category seems to perform better when purchased externally than when purchased from the DC but there are only one tenth of orders. Thus, the data is not sufficient enough to make a generalized claim.

FLU is using the DC as its default vendor better than FLU1. This is because low moving items are probably purchased from the DC, which is recommended. In addition, FLU2 externally purchased items are performing better than FLU1. Overall 72-hour availability for externally purchased items is 78.7%. As mentioned before, FLU2 has the general item code as well, but it does not have any effect on the overall situation.

FLU3:

FLU3 has the lowest total availability 79.9% (see Table 13). The results of the differences between externally purchased and internally purchased items are illustrated in Table 17. FLU3 purchases almost every item from X –category internally. Therefore, there are only -- purchases which are purchased externally (see Appendix 5). Thus, externally purchased X-items are not comparable. This issue repeats in every analyzed front line unit.

As mentioned earlier, the validity of the data is questionable or the parameter settings needs reconsidering.

Interesting fact is that, Z2 items generate most of FLU3 orders (see Table 13) and results shows that external vendors are performing better than the distribution center. Actually, the total 72-hour availability for external vendors is better than the availability to the distribution center. Surprisingly, the DCs 72-hour performance is only 73.2% in Z2 items whereas other front line units perform over 80%. As Appendix 5 shows, most of the Z2 orders come from category C. Almost 50% of all orders is generated by Z2-C class, which differs a lot when compared with other FLUs. This may be reason why FLU3 is performing the weakest of the evaluated front line units.

Table 17: *FLU3 availability & First Pick rates divided into external vendor and DC*

Local Category	External Vendor				Distribution center			
	Items	Orders	Avail. (+3d) %	First Pick (%)	Items	Orders	Avail. (+3d) %	First Pick (%)
X	**13,7 %**	**2,9 %**	**100,0 %**	**90,0 %**	**86,3 %**	**97,1 %**	**93,1 %**	**88,3 %**
A	14,6 %	3,1 %	100,0 %	88,9 %	85,4 %	96,9 %	93,4 %	87,8 %
B	12,5 %	3,4 %	100,0 %	100,0 %	87,5 %	96,6 %	85,7 %	85,7 %
C	0,0 %	0,0 %	-	-	100,0 %	100,0 %	100,0 %	100,0 %
Y	**9,4 %**	**13,3 %**	**81,4 %**	**90,0 %**	**90,6 %**	**86,7 %**	**91,7 %**	**88,8 %**
A	15,9 %	19,9 %	80,0 %	82,5 %	84,1 %	80,1 %	86,3 %	82,6 %
B	4,9 %	10,4 %	84,6 %	100,0 %	95,1 %	89,6 %	94,6 %	90,6 %
C	7,7 %	5,3 %	75,0 %	100,0 %	92,3 %	94,7 %	94,4 %	97,2 %
Z1	**13,1 %**	**13,2 %**	**68,3 %**	**71,7 %**	**86,9 %**	**86,8 %**	**84,3 %**	**82,3 %**
A	11,1 %	11,5 %	50,0 %	45,5 %	88,9 %	88,5 %	79,4 %	77,6 %
B	15,8 %	20,2 %	73,1 %	80,8 %	84,2 %	79,8 %	94,2 %	86,4 %
C	13,0 %	8,9 %	91,7 %	100,0 %	87,0 %	91,1 %	82,9 %	85,4 %
Z2	**32,6 %**	**28,2 %**	**84,3 %**	**91,3 %**	**67,4 %**	**71,8 %**	**73,2 %**	**77,8 %**
A	44,1 %	36,8 %	64,7 %	86,8 %	55,9 %	63,2 %	76,9 %	81,2 %
B	47,0 %	40,1 %	89,0 %	91,5 %	53,0 %	59,9 %	83,3 %	86,1 %
C	30,0 %	25,9 %	85,0 %	91,7 %	70,0 %	74,1 %	71,8 %	76,6 %
N	**8,5 %**	**8,1 %**	**65,7 %**	**65,7 %**	**91,5 %**	**91,9 %**	**82,4 %**	**77,2 %**
Total	**25,5 %**	**20,9 %**	**82,3 %**	**88,7 %**	**74,5 %**	**79,1 %**	**79,3 %**	**80,1 %**

FLU3 is performing well in X & Y categories and there is not much to be concerned with. The biggest challenges for FLU3 are in locally low moving items. As mentioned earlier, either the customer base for FLU3 is problematic or the item categorization is not proper for FLU3. Next, the thesis evaluates the stock levels to find out where the inventory value is.

4.5 Inventory analysis by stock value, TIDS and COGS

The overall situation by item category, the 12-month average stock value and the cost of goods sold is illustrated in Table 18. Total inventory days of supply (TIDS) is currently 187 days. X - category is the best performing category with a total of 67 days. Other categories' TIDS range from 77 to 147 days. Sub category C has the largest TIDS, which means that FLUs have a lot of low value items in stock, which follows the academic literature. Nevertheless, non-movable inventory increases the overall situation significantly. High value A – items are performing the best and their TIDS range from 66 to 91 days. It is notable that the general item code increases the TIDS by ten days but at the same time, it decrease the availability.

Table 18: *Item transaction by average stock value and COGS*

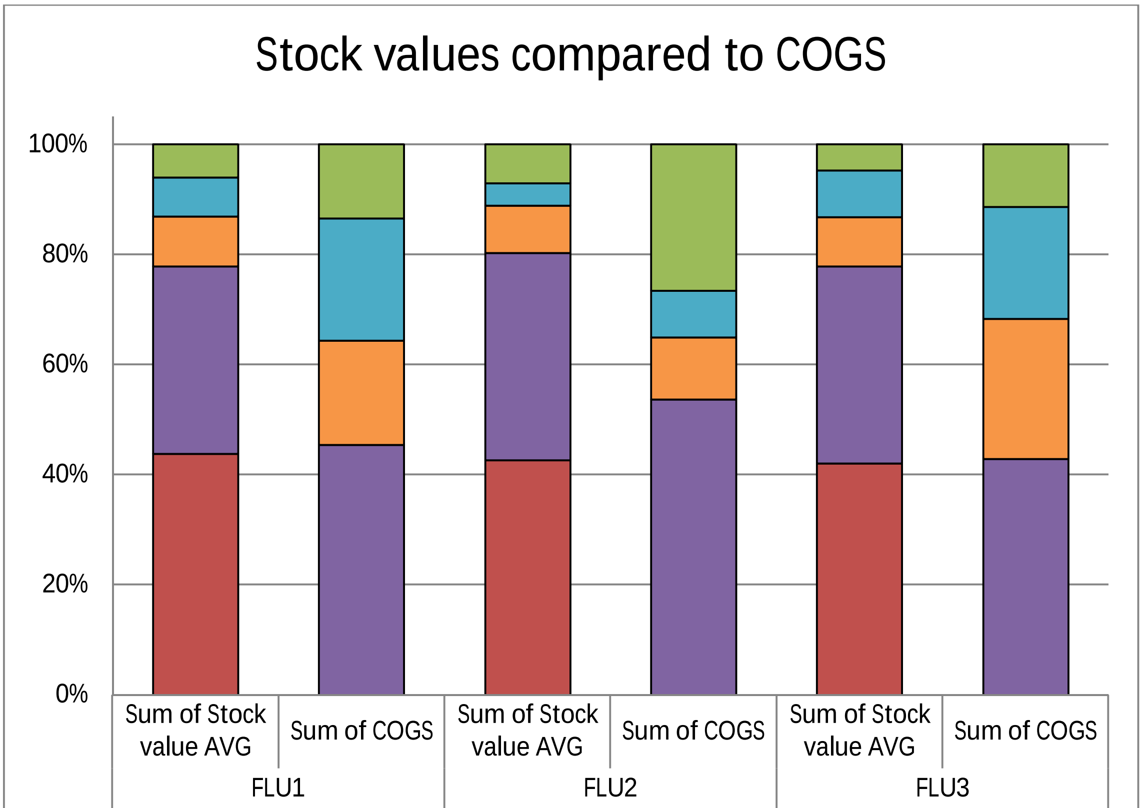
Local Cate-gory	Items	%	Trans-actions	%	Avg. Stock Value (M€)	%	COGS (M€)	%	TIDS
X	--	**0,6 %**	--	**43,0 %**	--	**6,0 %**	--	**16,7 %**	**67**
A	--	0,5 %	--	38,1 %	--	5,8 %	--	16,4 %	66
B	--	0,1 %	--	4,6 %	--	0,3 %	--	0,3 %	170
C	--	0,0 %	--	0,3 %	--	0,0 %	--	0,0 %	473
Y	--	**2,0 %**	--	**16,2 %**	--	**6,5 %**	--	**15,9 %**	**77**
A	--	0,8 %	--	6,9 %	--	5,0 %	--	14,2 %	66
B	--	0,8 %	--	6,5 %	--	1,3 %	--	1,6 %	152
C	--	0,4 %	--	2,8 %	--	0,2 %	--	0,1 %	273
Z1	--	**3,5 %**	--	**10,2 %**	--	**8,9 %**	--	**17,1 %**	**97**
A	--	0,8 %	--	2,6 %	--	5,8 %	--	14,9 %	72
B	--	1,1 %	--	3,1 %	--	2,3 %	--	1,9 %	228
C	--	1,6 %	--	4,5 %	--	0,8 %	--	0,4 %	398
Z2	--	**51,1 %**	--	**30,0 %**	--	**35,6 %**	--	**45,2 %**	**147**
A	--	2,7 %	--	2,5 %	--	14,9 %	--	30,5 %	91
B	--	6,5 %	--	5,0 %	--	11,4 %	--	10,5 %	203
C	--	42,0 %	--	22,6 %	--	9,3 %	--	4,2 %	411
N	--	**42,7 %**	--	**0,0 %**	--	**42,9 %**	--	**0,0 %**	**--**
GEN	--	**0,0 %**	--	**0,5 %**	--	**0,0 %**	--	**5,1 %**	**0**
Total	--	**100,0 %**	--	**100,0 %**	--	**100,0 %**	--	**100,0%**	**187**
NO GEN	--	**100,0%**	--	**100,0 %**	--	**100,0%**	--	**100,0%**	**197**

The current situation demonstrates that there are too many low-moving inventories in every evaluated front line unit. N –items cover 42.7% of all front line unit items and they will tie up 42.9 %, or (-- euros) in inventories. Also Z2 items, which have 1-5 transactions per year, tie 35.6% of the total stock value and they cover a total of over 50% of all items.

The literature review recommends that only locally high movable items and low-price items or otherwise critical items should only be stocked near the customer.

On the other hand, the most movable X items cover 6.0% of the average stock and they make up -- euros. Moreover, a number of X – items covers only 0.6% of all open items, so it is questionable is current item categorization parameters are correct for the business.

As the results shows, there are a lot of locally low moving items in the warehouses. The Z2-A items stock value is 14.9% of the total average stock value when these should be stored centrally. On the other hand, 42.0% of all open items are Z2-C –category and they tie up 0.40 million euros (9.3%) in total. In Figure 14, the situation is illustrated more clearly by different plants.



	FLU1 Sum of Stock value AVG	FLU1 Sum of COGS	FLU2 Sum of Stock value AVG	FLU2 Sum of COGS	FLU3 Sum of Stock value AVG	FLU3 Sum of COGS
X	6,07%	13,49%	7,06%	26,64%	4,78%	11,34%
Y	7,08%	22,16%	4,03%	8,47%	8,50%	20,36%
Z1	9,06%	18,95%	8,61%	11,26%	8,84%	25,52%
Z2	34,00%	45,39%	37,73%	53,63%	35,89%	42,79%
N	43,79%	0,00%	42,58%	0,00%	41,99%	0,00%

Figure 14: *Average stock value in the year 2105 and generated COGS by category*

As the above image illustrates, every plant average stock value approximately consists of 80% of the items which have 0-5 transactions per year. As the literature review tells, these items should be stored at the distribution center, and especially low moving but high value items should be stored at the distribution center. As Table 18 shows, Z2-A and Z2-B items tie up 26.3 % of the total inventory value.

Figure 14 shows that FLU2 is generating the most sales in X – category compared to its total sales. On the other hand, FLU1 has the most N & Z2 stock value whereas FLU3 has almost the same warehouse structure as FLU1. To figure out why front line units have a lot of non-moving stock, this item category needs closer investigation. One of the reasons is the local item codes. The item is local when it is not open for the distribution center. Thus, the local item codes are analyzed in the following chapter.

4.5.1 Local items analysis

Every warehouse has items, which are only locally open. This is because previous front line units had permission to open own item codes. Local item codes are problematic because they cause item duplicates, thus increasing stocks and decreasing availability because the replacement parts cannot be found on time. In Table 19, these items are collected by front line unit.

Table 19: *Local items by warehouse*

FLU	No. of all items	No. of local items	%- of all items	Total COGS	Total COGS, local items	% of total COGS
FLU1	--	--	51,0 %	--	--	24,4 %
GEN	--	--	-	--	--	*12,7 %*
FLU2	--	--	4,4 %	--	--	8,0 %
FLU3	--	--	18,6 %	--	--	18,3 %
Total	--	--	**28,8 %**	--	--	**22,2 %**

Over 50% of FLU1's warehouse open items are not open globally. Furthermore, almost 37% of its annual COGS are covered by local items. From a central operations and an item management point of view, the same items need to be unified to see complete consumption for a certain item. There are thousands of items which most certainly have Case Company code as well. This will cause availability problems for the front line unit in such a case that an external vendor cannot supply the items and central operations does not have item-specific information. In addition, the general code is separated to clarify its problem. A cost of goods sold for this one item code is considerably high at -- euros, with total quantity of – in -- different transactions. It is obvious that this will affect the overall situation. Moreover, other site warehouses have general items codes as well but they are not using it on the same scale as FLU1. These general item codes are supposed to be used when a certain item is one of a kind and it needs to get through the processes. Currently, FLU1's site warehouse are using the general item code to buy almost everything from normal bolts to complete engines.

FLU2 has only minor issues with local item codes. In addition, FLU3's local item codes generate almost 20% of its annual COGS which is less than in FLU1, but still most certainly affects availability. The next sub-chapter takes closer look at non-moving items.

4.5.2 Non-moving items analysis

Table 20 lists non-moving items by warehouse. The total stock value is -- euross (42.9% of total stock). Items which are locally open cover 38.6% of total non-moving stock value. This issue is critical especially for FLU1 because the local item codes value covers 66.4% (-- €) of their total non-moving stock. Also FLU3 has problems with local item codes, because they cover 32.0% of the total non-moving stock. FLU2 does not have problems with local item codes, but their non-moving stock is still vast.

Table 20: *Non-moving items by warehouse*

Plant	N-Items	N-items avg. stock value (€)	% of total stock	Local N-Items	% of local items	Local items avg. stock value (€)	% of total non-moving value
FLU1	--	--	43,8 %	--	71,8 %	--	66,4 %
FLU2	--	--	42,6 %	--	2,4 %	--	2,4 %
FLU3	--	--	42,0 %	--	21,7 %	--	32,0 %
Total	--	--	**42,9 %**	--	**41,7 %**	--	**38,6 %**

To get a better view of the current situation, this thesis analyzes where the non-moving stock is located. The reporting system gives information about which echelon each item is located. Therefore, it is valuable to evaluate where the non-moving items are. In addition, it is valuable to analyze them by global category to find out whether the global items are moving.

Table 21 illustrates the inventory value by global category divided by storage location. The result shows that 29.4% of non-moving items are located at either customer site or in maintenance vans. The rest of the non-moving items are in the 2nd echelon warehouses.

Table 21: *Locally non-moving inventory value by global category divided into echelons in December 2015*

Global Category	Total						Grand Total
	Site		Van		WH		
X	--	25,4 %	--	42,1 %	--	32,5 %	--
Y	--	18,2 %	--	29,8 %	--	52,0 %	--
Z1	--	15,5 %	--	18,7 %	--	65,9 %	--
Z2	--	12,0 %	--	9,1 %	--	78,9 %	--
N	--	5,3 %	--	7,6 %	--	87,1 %	--
Local items	--	29,4 %	--	4,5 %	--	66,0 %	--
Total	--	**18,4 %**	--	**11,1 %**	--	**70,6 %**	--

The above results show that 36.1% of the locally non-moving inventory value is globally moving. In Appendix 3, locally non-moving items are divided by plant. It shows that 23.7% of the total locally non-moving items in FLU2 are located in maintenance vans. Moreover, 78% of vans' non-moving inventory value is globally active. Therefore, it is completely unnecessary to carry non-moving items in maintenance vans. The total inventory value can be reduced by 21% if globally moving and locally non-moving items are returned to the central warehouse. However, this is not so conclusive, because an item may be stored by request or for other reasons.

4.6 Current situation conclusions

Currently, the Case Company uses academically recognized stocking principles. Stock replenishment is done by using a perpetual system. Moreover, stock levels, re-order points and economic order quantities are defined and monitored by complex software. The Company uses a multi-echelon inventory system which is a standard requirement in the global spare part business. The multi-echelon inventory is used as the literature review suggests; most of the items are purchased from a distribution center and the local vendors are also used. Furthermore, different types of special deliveries are used in special cases, such as direct deliveries to customers in "machine down" situations.

Item categorization takes quantitative aspects into account: price, quantity and transaction volume are basic principles for the Case Company's item categorization. These are also noticed by academic literature. Furthermore, the judgmental aspect is taken into account, but it is only used in the distribution center.

From a management point of view, there are multiple areas of improvement. Firstly, monitored KPIs are either inaccurate or they do not serve the customer. Total inventory days of supply includes unnecessary figures and therefore it does not give accurate information about inventory turnover. Secondly first pick rate seems to give misleading information about the Case Company's performance.

The reporting system has some areas which require critical improvement. Firstly, the reporting system gives the information by global indicators which proves misleading for front line units. Secondly, the performance measurement excludes a lot of ordered lines and therefore its provided information is incomplete.

Future forecasting is done by software and it will use forecast methods noticed by academic literature such as average, weighted average and exponential smoothing which are all commonly used in the spare part business. All forecasting methods are evaluated by MAPE calculations and the best-fitted forecasting method is used. Nevertheless, even though the literature's evidence show that current forecasting methods tend to overestimate, they are still in use.

A couple of deviances are found comparing the current situation with literature. The Case Company does not include demand variability into account in item categorization which has been in researchers' spotlight in recent years. Even though, the forecasting software has an option to use Croston's method in forecasting, this method is not in use.

As availability analyses show, different front line units have different challenges even though they might seem to perform similarly at first sight. Furthermore, analyses show that the distribution center is performing better than external vendors. Therefore, it is recommended that front line units should use the distribution center more as a default vendor and use local vendors only for oils, liquids and other special items. Moreover, front line units should concentrate on monitoring their local vendors. The current situation shows that the evaluated warehouses have the possibility to increase their availability.

As previous chapters show, every evaluated plant has considerably high non-moving stock value. For better performance, it is clear that locally non-moving stock should be returned to the distribution center or scrapped because these will cause unnecessary holding costs and it may lead to spoilage or loss. Furthermore, every plant has a lot of local item codes, especially in FLU1. Moreover, FLU1 is the only frontline which uses its general item code regularly which causes distortion in the calculations.

Despite the literature review's recommendation, every evaluated front line unit high moving X and Y categories stock value are lower than low moving categories. Alternatively, the number of high moving items is also low. Management needs to reconsider whether or not they keep the current item categorization the same and keep the most important items quantity low, or should they consider implementing new item categorization to increase the number of the most important items.

Literature recommends that front lines concentrate more on high moving items, but actual emphasis of inventory values is on low moving items. It is clear that the warehouse could lower their inventory value and turnover significantly without decreasing the availability when locally slow moving items are returned to the distribution center if possible.

In the next chapter, the thesis evaluates improved warehouse performance metrics by hypothetically adjusting the warehouses in accordance to the findings from the literature review. First, the thesis analyzes the locally high moving items' adjustment. Secondly, the thesis evaluates how the locally intermediate moving stock could be adjusted. Finally, thesis analyzes the locally low and non-moving items and evaluates how the changes affect inventory value.

5. RESULTS AND DISCUSSION

5.1 Increasing X & Y items inventory

As literature recommends, front line units should concentrate on high moving items. Therefore, additional stock should be added for high moving items to improve KPIs and moreover, improve customer satisfaction. After a short discussion with management, X & Y - items mathematical service level is increased to 96% and therefore safety factor k is 1.76 (see Stevenson 2009, p. 881). The new stock value is calculated with the safety stock calculation illustrated in 2.5, multiplied by item price. The new average stock value is calculated if the following rules are fulfilled:

- The item is globally open
- If Avg. stock value of certain item < calculated value of certain item

A total of -- items are within this scope. The results of the increased inventory value are illustrated in Table 22.

Table 22: *X & Y inventory value difference, when mathematical service level is 96%*

	FLU1	FLU2	FLU3	TOTAL
	X –items			
Old X- items avg. value (€)	--	--	--	--
New X- item avg. value (€)	--	--	--	--
Difference	0,1 %	0,0 %	0,2 %	**0,1 %**
	Y-items			
Old Y-items avg. value (€)	--	--	--	--
New Y-items avg. value (€)	--	--	--	--
Difference	18,8 %	33,9 %	9,3 %	**18,3 %**
	Impact on total inventory value			
Items in scope	--	--	--	--
Old avg. stock value (€)	--	--	--	--
Total increase (€)	--	--	--	--
Difference on total stock	+1,3 %	+1,4 %	+0,8 %	**+1,2 %**

As the table shows, increasing the mathematical service level for X & Y items have a minor impact on the total average stock value. The X-items stock value increases only by 0.1%, whereas Y-items average stock increases by 18.3%. However, when adjusted, the total inventory value increases by only --€, which has an overall impact of 1.2% on the total inventory value. Biggest changes in euros is in FLU1 and FLU2 inventory value increase most in percentages.

It is difficult to estimate the effects of the aforementioned action on KPIs, because future data is not available. It would be valuable to increase the mathematical service level slightly over a time. With this action, stock level does not increase rapidly. It is also valuable to consider where to buy high moving items. As Table 14 shows, items which are purchased from a distribution center perform better than externally purchased items. Because of this, X&Y items should be purchased from a DC when possible in order to achieve better availability. External vendors should be used as a backup in shortage situations.

5.2 Evaluating Z1 items

Z1 items have 6-11 transactions in the past 12 months. In the year of 2015, the Z1 average stock value was -- million euros which is only 8.9% of total stock value. This item categorization stock value should be increased to gain better customer satisfaction. When current 72-hour availability for Z2 –items is 87.3% (see Table 8), it is recommended to increase the stock. The item needs to be globally open, because previous chapters prove that local item codes cause distortion and it is not recommended to use them. Thus, they are excluded from this analysis. The new average stock value is calculated if the following rules are fulfilled:

- The item is globally open
- The item local code is Z1

After a discussion with management, the desired mathematical service level for intermediate moving Z1 items is 88%. Therefore, the new stock value is calculated with the safety stock calculation illustrated in Chapter 2.5. The safety factor (k) for 88% service level is 1.18 (Stevenson 2009, p. 881). Safety stock is multiplied with an item MAP price to get the new stock value. The total number of items in this evaluation is -- and the value impact is -- euros. In Table 23 illustrates the impact of increasing Z1 items.

Table 23: *Z1 items inventory value increase, when mathematical service level is 88%.*

	FLU1	FLU2	FLU3	TOTAL
	Z1 Items			
Items in scope	--	--	--	--
Old Z1 items avg. value (€)	--	--	--	--
New Z1 items avg. value (€)	--	--	--	--
Difference	19,2 %	14,1%	36,0%	22,1%
	Impact to total stock			
Old avg. stock value (€)	--	--	--	--
Increase (€)	--	--	--	--
Difference	+1,7%	+1,2%	+3,2%	+2,0%

As the above results show, the impact on total stock value is only 2.0%, when desired mathematical service level for Z1 items is increased to 88%. The biggest changes in the stock value are at FLU3. On the other hand, FLU3 has the weakest 72h availability and therefore increasing the stock is recommended. The least impact will be in FLU2. Thus, it has the best 72h availability in Z1 category.

Z1 items are an important item group because they will generate 11-25% of total COGS in every FLU. As availability analyses indicate, Z1 items which are purchased from the distribution center, the 72-hour availability performance is over 90% in every evaluated plant. Thus, Z1 items should be purchased from the distribution center. Moreover, even straight deliveries from the DC are recommended in urgent situations.

5.3 Returning locally low moving items to DC

The current situation shows that front line units have extensive amount of locally low moving stock. The next step is to send locally low moving stock back to the distribution center. Because FLUs have a lot of local item codes, it is clear that these items cannot be sent back because the DC does not recognize them. In addition, low price items do not need to be sent back, because the transportation costs would exceed the item price. Moreover, item needs to be globally moving, because otherwise the items stays at the DC. New average stock value is calculated if following rules are fulfilled:

- Item has 0-5 local transactions in the year 2015. (N, Z2 items)
- Item is globally moving and open
- Item average price is over 10,00€ / piece
- Item stock quantity in December 2015 is > 1

The result shows that there are -- items on scope. The total cost reduction is over -- euros. The impact of action is illustrated in Table 24. The results are divided into three different phases. First locally non-moving items are analyzed, then Z2 -items inventory reduction impact on total stock is analyzed. Finally, presented is the additional potential which comes from items which have the local item code, but they do not have movement.

Table 24: *Stock value reduction after removing locally low moving and globally moving items.*

Plant	FLU1	FLU2	FLU3	TOTAL
Total items	--	--	--	--
Average stock value (€)	--	--	--	--
Local N, Globally moving, price >10 €				
Items	--	--	--	--
Stock Value	--	--	--	--
Reduction	-4,3 %	-19,2 %	-10,0 %	**-10,2 %**
Local Z2, Globally moving, price > 10€				
Items	--	--	--	--
Stock Value	--	--	--	--
Reduction	-12,3 %	-25,3 %	-14,2 %	**-16,7 %**
Immediate reduction, total				
Stock value reduction	--	--	--	--
%- of Total stock	-16,6 %	-44,5 %	-24,1 %	**-26,9 %**
Potential reduction: Local N, Local item code, price > 10€				
Items	--	--	--	--
Stock value	--	--	--	--
Additional potential	-21,0 %	-0,9 %	-11,8 %	**-12,6 %**

As the results shows, it is possible to decrease the total average stock value immediately by -26.9%. The warehouse in FLU2 has the largest potential for stock reduction with locally low moving items, with a total of -44.5%. FLU2 does not use 3rdrd party planning software which may explain why it has so much non-moving stock. Their stocking policies are based mainly on warehouse management experience. It may be the cause why unnecessary stock is greater in FLU2 than other warehouses. Moreover, almost every non-moving item in the FLU2 warehouse is globally moving. Therefore, they could achieve it most easily. As Appendix 3 shows, referring to the situation in December 2015, a lot of non-moving items are located in 3rdrd echelon. In addition, it is recommended that stocktaking is done at least once a year.

Because of local item codes, these items cannot be sent back to the distribution center. In an ideal situation, there are minimal numbers of local item codes. If the local item codes are identified, FLUs could send them back to the distribution center or sell them locally. The additional potential of stock value reduction is -12.6%. As Table 24 illustrates, FLU1 has the least straight potential to reduce their stock. Local item codes are generating an extensive amount of non-moving stock. Therefore, it needs to either find a customer for non-moving stock or find a replacing global item code for these items, because scrapping these items would be a substantial expenditure for the company.

As tables in chapter 4.4.3 show, direct deliveries 72-hour availability is over 95% from the distribution center in both, Z2 &Z1 items. Therefore, if assuming that the distribution center can perform at the same level of performance with a larger amount of items, it is recommended that locally low moving items should be delivered straight from the DC to achieve the targets rather than be delivered from front line unit warehouses.

5.4 Evaluating results

5.4.1 Results of inventory adjustments

Appendix 6 illustrates the new possible situation. As we can see, TIDS drops significantly to from 197 days to 143 days. Moreover, the stock value decreases by -- euros (-23.7%). On the other hand, this will increase the inventory value of the distribution center temporarily. Since, all items which are recommended to be sent back to the DC are globally moving, the DCs' inventory value will return to normal. These actions should not have any effect on items' 72-hour availability or first pick percentages. Alternatively, increasing the X, Y and Z1 items stock value, the availability should increase. Current average stock and calculated stock difference is illustrated in Figure 15.

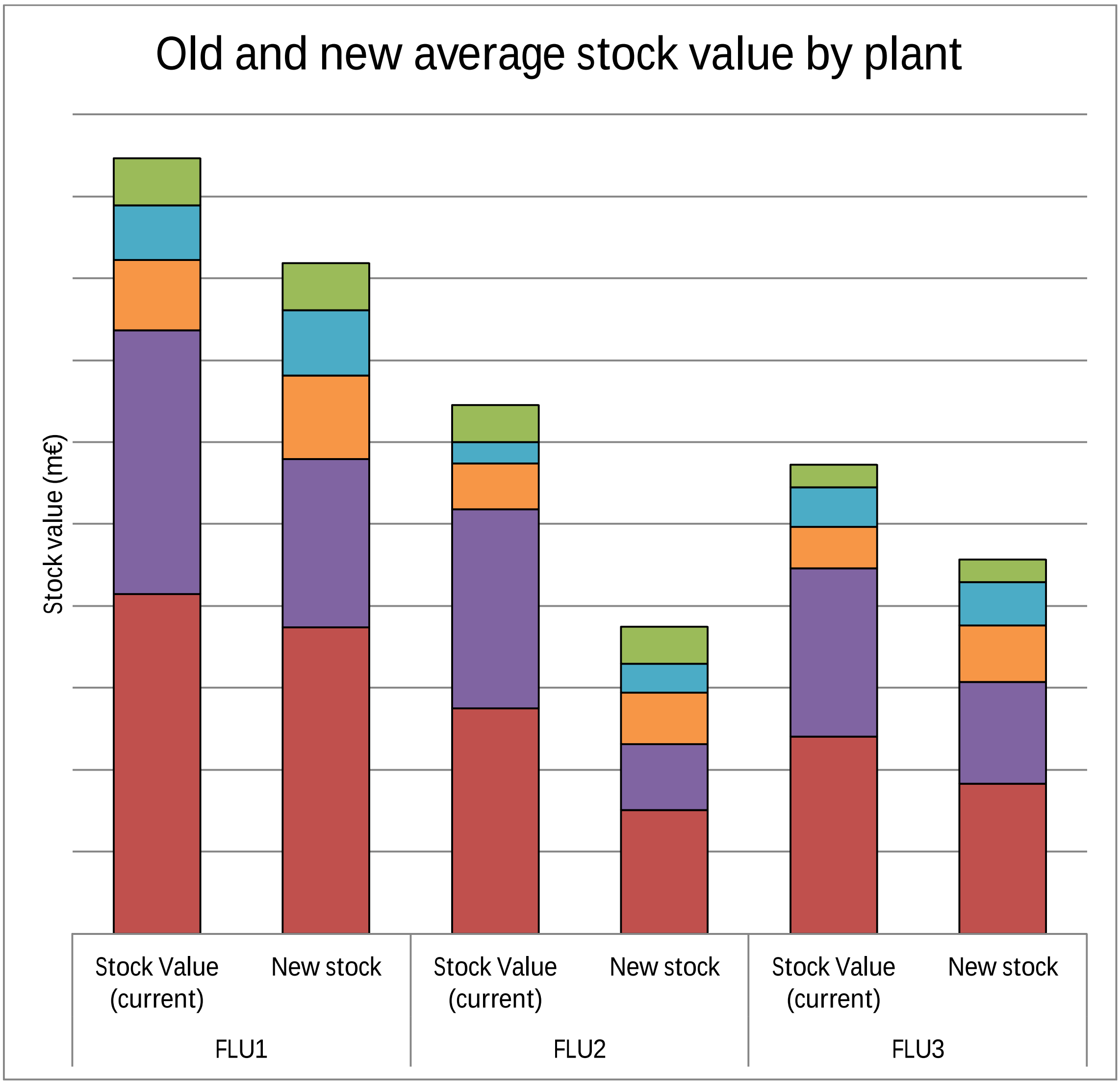


Figure 15: *Current average stock value compared possible new stock value*

FLU2 has the best possibility to reduce its stock. They also have opportunity to reduce their warehouse value by 41.9%. At the same time, its TIDS decreases from 164 to 96 days. In an ideal situation, there is no locally non-moving stock. In practice this is extremely hard to achieve, because of an uncertain demand for items. Therefore, there is always some non-moving stock. Even though FLU2 could reduce its non-moving category by -45%, its still non-moving stock of potential new stock value is over 40%. A possible reason for this is that the spare part business is generally a really difficult business area in which the number of items is vast and the demand is sporadic. It is an interesting conclusion that FLU2 is the best performing FLU in every KPI and it has the best opportunity to improve its KPIs even though they do not use the planning software on a full scale.

The FLU1 inventory structure is the most problematic because of an extensive number of local item codes. As a recommendation, FLU1 needs to stop using general item codes, because the evaluation shows that general item codes cause a lot of distortion in calculations. Furthermore, the local item codes should be reduced, because they decrease the availability. Moreover, large numbers of local item codes are non-moving which increases the excess stock and they cannot be identified in the DC.

As a recommendation, every front line unit needs to make stocktaking at least twice a year in the main warehouse and the site locations as well. As Appendix 3 shows, 3rdrd echelons holds vast amount of money. Moreover, currently other front line unit warehouse data is not available for other front lines. By opening the data for all front lines, they can check other front lines stock levels if the part is available. This reduces the delivery time to the customer. Recalling that item data need to be consistent.

5.4.2 Results of availability analyses

Every evaluated front line unit has relatively small amount of high moving X and Y -items in their stock which they should concentrate on. Therefore, it is recommended that they need to increase their inventory value to achieve better performance in these categories. When possible, locally high moving items should purchase from the distribution center, for the distribution center performs better than local vendors in these items. Local suppliers are used only for liquids and the local item codes. However, the number of local item codes need to start decreasing systematically. Furthermore, Z2 items need to be stored as well. Straight deliveries from a supplier are used only in special circumstances. These special cases may be either large frame deliveries or in extremely urgent machine down situations.

First pick and 72-hour availability changes cannot be evaluated because of the time restrictions of this thesis. It is obvious that if X, Y and Z1 categories stock value increases and locally low moving items stock value decreases, front line units are concentrating more on the items which are the most crucial in their geological area.

Figure 16 illustrates how item flow should be organized. Globally open items need to be purchased from the distribution center. Furthermore, globally open items which are in the locally low moving Z2 category should be delivered straight from the distribution center because analyses show its superiority in low moving items.

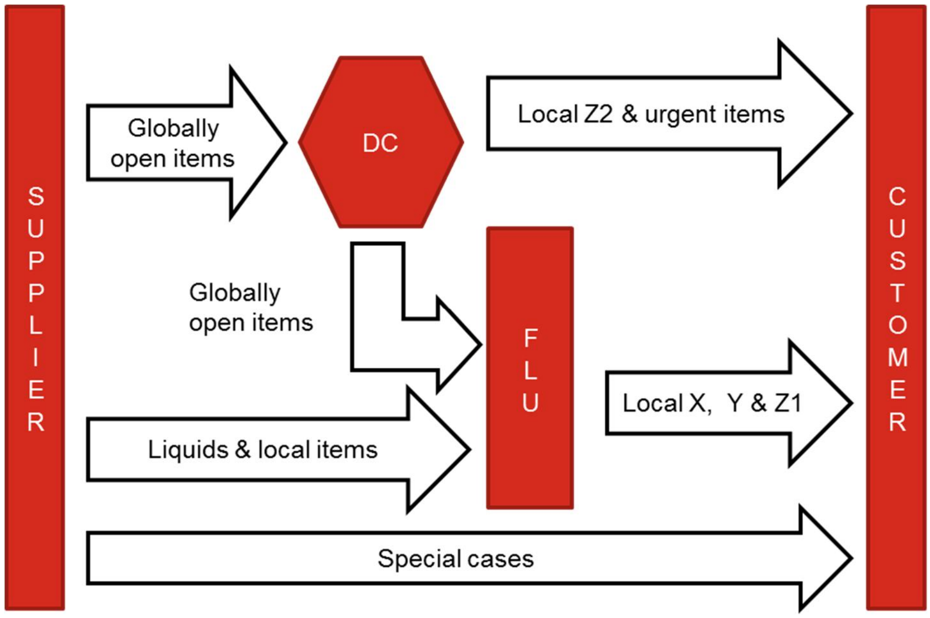


Figure 16: *New item flow for different categories*

As analyses in Chapter 4.4.3 show, it is strongly recommended that locally low moving items are delivered straight from the DC. This is because of the DC is performing better than deliveries from the local warehouse in every evaluated plant. Furthermore, front line units should focus on ordering from the distribution center, because it is evidentially showed that items which are purchased from the distribution center can perform better than locally purchased items. On the other hand, local suppliers should be used to encountering possible shortage situations. Moreover, local suppliers are needed to purchase liquids and other local items. Because this thesis does not evaluate the purchasing prices, there may be economic reasons why FLUs are purchasing items locally.

General item codes cause distortion to calculations. Purchasing and selling items under this item code may cause a situation in which the system does not recognize possible stock keeping units if the certain item is sold under a general item code. Therefore, it is extremely important to use Case Company codes whenever it is possible.

5.4.3 Results from the management point of view

From the management point of view, there are multiple areas for improvement including how to improve internal actions in the Case Company. Firstly, some of the key performance indicators are miscalculated. Currently, total inventory days of supply (TIDS) includes unnecessary costs, which causes distortion. TIDS should include only the costs which have accumulated when the item is sold. Secondly, “availability” is a misleading word concerning the on-time departure from the warehouse. Therefore, the thesis recommends change labelling of 24-hour and 72-hour availability to something more descriptive, for instance, on-time departure (OTD). In addition, the first pick rate does not measure the Case Company’s performance. This can be explained by a simple example. If a hardware store measures its customer satisfaction by the described first pick rate - Is the customer happy if he/she orders a hundred four inch-nails but gets only ten of them? In this scenario, the customer will most certainly go somewhere else. Thus, the Case Company needs to start using an order fill rate instead, which measures is the ordered line in stock or not.

Another area requiring improvement is the reporting system. Currently, the reporting system gives all the information by global indicators. Table 8 and Table 9 illustrates the difference. Global indicators say that X-category covers 25.7% of all items and the 72-hour availability is 91.7% in front line units, but the reality is that they cover only 1.95% and their performance is only 88.2%. Hence, it is extremely important to get local categories as part of the reporting system so front lines can get relevant information for their performance. Additionally, the reporting system excludes a lot of ordered lines. It would be really valuable to the whole company if they could monitor the service contract performance as well. The whole reporting system can be questioned if it includes only 40% of all transactions. Lastly, the reporting system has lines which cause distortion. Raw reports include freights which have an effect on all indicators.

The item categorizations need to be re-evaluated. As Chapter 4.4's results show, the demand in different categories widely varies between front line units. Therefore, it is valuable to consider XYZ –categorization borders in front line units separately. With this action, each front line unit can evaluate their borders individually and get the most important items under a tighter scope.

As a result, the company could reduce their inventory holding cost significantly and at the same time, improve their customer satisfaction. Rapid actions can be taken by sending locally non-moving items back to the distribution center. As a result, the inventory days of supply decreases from 187 days to 143 days. However, better customer satisfaction would be achieved if item flow is restructured. Moreover, changes to the reporting system must be made so front line units can get relevant data to find the most important items.

6. CONCLUSIONS

6.1 Main results and recommendations

The purpose of this thesis is to evaluate front line unit warehouse performance and find solutions by reviewing literature on how to improve multi-echelon inventory system front line unit KPIs without decreasing the current service levels. It was done by using the Case Company's reporting system's given information to evaluate the current situation from the year of 2015. Furthermore, the chapter assesses the study and results. Recommendations for further studies are also given.

In the literature, there is no universal best practice on how spare part inventory management should be done. However, to achieve success in a spare part inventory management, there are simple rules. First and foremost, the customer(s) need to be remembered in every and all situations, especially in businesses where the customer machine uptime rates are a vital part of their success, in which case they will demand fast deliveries. Secondly, item categorization is a standard requirement because normally the number of stock keeping units is extensive in spare part businesses. Thus, items are more easily handled as a group. The categorizations needs to be suitable for company's business and the amount of different categorizations needs to manageable. Furthermore, categorization needs to take in account both qualitative aspects and quantitative aspects. Thus, management can get a wide range of stock keeping units.

Different item categorizations need different targets and forecasting methods. In a multi-echelon inventory system, the front line needs to concentrate on the most demanded items whereas the distribution center can distribute the locally low moving items. If the company does not have any complex automated forecasting software in use, the forecasting methods need to be easy to use and understand. Low price items may be monitored by periodical review, but high price and highly demanded items need to be in tight scope.

The multi-echelon system performance needs to be monitored as a whole or otherwise, site locations fall to sub-optimize their performance which decreases the total performance of the system. Monitoring happens by using certain KPIs. KPIs need to be relevant and the same to all locations so that management can find the improvement areas and internally benchmark each warehouse performance.

After all of the abovementioned actions are done, management needs to review all actions taken periodically and further develop their inventory management system. As an example, after The Case Company has achieved 72-hour on time departure targets, the company can start to reduce the targeted time frame.

All in all, inventory management is not only looking at internal performance. The supply chain needs to be evaluated as a whole. Suppliers' performance have significant influences the company's performance as well. Moreover, spare part companies need important information from customers as well, so they could make proactive actions to achieve high levels of customer satisfaction.

6.2 Recommendations for practice and managerial implications

As a result, the Case Company need to make the same kind of evaluation to all front line units as is carried out in this thesis. Actions for lowering the inventory value is to send a list of returnable items to the front line units which are ranked by their inventory value. First returnable items hold most of the current inventory. After that front line units need to establish clear rules on how the stocktaking is done periodically.

When the most expensive items are returned, the long-term mission is to improve the reporting system and key performance indicators so that they are more accurate. Current reporting systems and key performance indicators are not reliable enough. KPIs by global indicators do not give the best information for front line units. Moreover, example freight are included the reports which cause distortion. Therefore, it needs unnecessary recourses to fix reports which can also cause some miscalculations.

When the abovementioned actions are taken, management should consider taking in account the qualitative methods in item categorization as well. Because the ERP system allows FLU to determine their critical parts, it is valuable to use. Customers have items in which the demand can be extremely rare, but they could be critical. Therefore, front line units should have a decent framework to evaluate which items are critical.

6.3 Assessment of the study

The Case Company's reporting system was widely used in this thesis. In addition, a lot of data combinations from different reports are used. Thus, the results of this thesis should be viewed critically. Moreover, the Case Company's reporting system has a lot of lines which cause distortion. Although, the most effective ones have been excluded, reports may still contain some lines which cause distortion. Secondly, because the reporting system does not give local item categories, they were manually calculated for this thesis. Therefore, depreciation of items may cause that some items' inventory value will decrease to zero which leads to the miscalculation of generated COGS.

The reliability of availability reports can be also questioned. Some of the figures include only a small number of orders. Therefore, the numbers need to be evaluated carefully before making any assumptions. The superiority of the distribution center can be criticized as well. This analysis did not take into account neither the item prices nor the lead times. These are critical aspects when considering the best supplier for different items.

This thesis was purely quantitative and therefore management opinions are excluded. Moreover, no discussions were held with a person responsible for front line unit managers or reporting systems. Therefore, there may be multiple hidden reasons for why everything is done the way it is currently done. On the other hand, the thesis gives the statistical perspective of current situations.

This study concentrates on a single case study thus the results are company specific. It creates some limitations to the theoretical implications of this study. However, this thesis provides a framework for item categorization, stocking location decisions and performance measurement principles for companies within a similar area of business.

6.4 Recommendations for further studies

The current cheap parts purchasing policy can be criticized. Because The Case Company's spare part inventory portfolio includes a lot of different items in which prices vary from really cheap "bulk" materials to extremely expensive motors, the different purchasing policies would be valuable to research. Automated purchasing or a vendor managed inventory for cheap parts is an interesting area of research. When cheap parts are purchased as needed, ordering costs could be more than the item part's costs itself. Therefore, it would be valuable to combine the same type of cheap parts under one supplier and use a fixed ordering interval instead of the current purchasing policy.

The current item categorization does not include demand fluctuation as part of the categorization policy, which is where recent academic literature is concentrated. Therefore, item categorization based on demand patterns and its effect on item categorization are interesting fields of future research.

Purchasing policies and item flow from supplier to the company inventory system is an interesting field of research. For instance, how does the performance and inventory value change if the company changes its warehousing strategy from a multi-echelon inventory system to a single inventory system? Moreover, the current item flow mostly goes through the distribution center. It would be really valuable to research the possibility of the company shifting item flow so that it comes mostly from local vendors and the distribution center only serves as a backup with global contracts with suppliers.

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APPENDIX 1: SUMMARY OF STUDIES ON SKU CLASSIFICATION IN SPARE PART MANAGEMENT (ADOPTED FROM VAN KAMPEN ET AL. 2012, P. 857-861)

		Charasteristics			
Aim	**Industry**	**Volume**	**Product**	**Customer**	**Timing**
IM	**Spare parts in process industry**	Demand volume	Unit costs	Criticality, number of installations	
IM	**Spare parts (general)**	Demand volume, Demand size variability	Unit costs	Criticality	
IM	**Automotive spare parts**	Demand volume + returns volume	Unit cost, product life cycle, lead time, number of vehicles used	Criticality	Seasonality factor
IM	**Manufacturing and service firm (Spare parts)**	Demand volume	Unit cost, lead time, criticality	Impact of criticality	
IM	**Manufacturing (spare parts)**			Criticality	
FOR	**Spare parts in aviation industry**	Demand size			Mean inter-demand interval
IM	**Spare parts in general**	Demand volume	specificity, unit costs	criticality	Inter-demand interval
IM	**Spare parts in HI-tech & manufacturing industry**	Demand volume	Lead time		Seasonal patterns
IM	**Spare parts in pharmaceutical industry**	Demand volume (annual)	Unit cost, ordering cost, lead time		
IM	**Spare parts in general**	Demand volume (annual)	Unit cost, lead time	Criticality	
IM	**Spare parts in oli refinery**	Demand volume (monthly)	Unit cost	Criticality	
FOR	**Spare parts in agricultural machinery**	Demand volume (annual)			

FOR = Forecasting

IM = Inventory management

APPENDIX 2: AVAILABILITY EVALUATIONS BY PLANTS

Cate-gory	Items	Lines	BO lines (+1d)	No BO (+1d)	% (+1d)	BO lines (+3d)	No BO (+3d)	% (+3d)	Straight pick	No first pick	First pick (%)
FLU1	--	--	--	--	**67,3 %**	--	--	**81,3 %**	--	--	**83,8 %**
X	--	--	--	--	**92,1 %**	--	--	**94,4 %**	--	--	**98,6 %**
A	--	--	--	--	93,2 %	--	--	95,5 %	--	--	98,6 %
B	--	--	--	--	81,3 %	--	--	84,0 %	--	--	98,7 %
C	--	--	--	--	100,0 %	--	--	100,0 %	--	--	100,0 %
Y	--	--	--	--	**74,9 %**	--	--	**88,3 %**	--	--	**89,4 %**
A	--	--	--	--	74,0 %	--	--	89,5 %	--	--	87,8 %
B	--	--	--	--	88,8 %	--	--	95,7 %	--	--	93,5 %
C	--	--	--	--	52,5 %	--	--	71,4 %	--	--	86,6 %
Z1	--	--	--	--	**68,9 %**	--	--	**84,3 %**	--	--	**83,9 %**
A	--	--	--	--	73,9 %	--	--	88,8 %	--	--	78,4 %
B	--	--	--	--	78,7 %	--	--	91,3 %	--	--	87,3 %
C	--	--	--	--	60,8 %	--	--	78,1 %	--	--	84,7 %
Z2	--	--	--	--	**62,4 %**	--	--	**78,9 %**	--	--	**80,2 %**
A	--	--	--	--	73,9 %	--	--	89,6 %	--	--	87,2 %
B	--	--	--	--	80,2 %	--	--	91,0 %	--	--	84,7 %
C	--	--	--	--	58,8 %	--	--	76,2 %	--	--	79,0 %
N	--	--	--	--	**81,3 %**	--	--	**81,7 %**	--	--	**69,1 %**
GEN	--	--	--	--	**24,3 %**	--	--	**42,5 %**	--	--	**77,9 %**
FLU2	--	--	--	--	**83,6 %**	--	--	**88,3 %**	--	--	**87,5 %**
X	--	--	--	--	**80,7 %**	--	--	**86,1 %**	--	--	**95,2 %**
A	--	--	--	--	81,3 %	--	--	86,7 %	--	--	95,3 %
B	--	--	--	--	75,2 %	--	--	81,5 %	--	--	95,2 %
C	--	--	--	--	83,3 %	--	--	83,3 %	--	--	83,3 %
Y	--	--	--	--	**85,0 %**	--	--	**91,7 %**	--	--	**91,9 %**
A	--	--	--	--	86,4 %	--	--	93,8 %	--	--	92,0 %
B	--	--	--	--	83,0 %	--	--	88,7 %	--	--	91,8 %
C	--	--	--	--	87,7 %	--	--	96,1 %	--	--	91,6 %
Z1	--	--	--	--	**87,0 %**	--	--	**92,3 %**	--	--	**89,1 %**
A	--	--	--	--	83,7 %	--	--	90,5 %	--	--	90,5 %
B	--	--	--	--	85,5 %	--	--	91,8 %	--	--	88,8 %
C	--	--	--	--	92,9 %	--	--	95,1 %	--	--	88,0 %
Z2	--	--	--	--	**80,1 %**	--	--	**86,7 %**	--	--	**88,3 %**
A	--	--	--	--	73,2 %	--	--	81,9 %	--	--	86,4 %
B	--	--	--	--	78,3 %	--	--	86,9 %	--	--	89,6 %
C	--	--	--	--	82,0 %	--	--	87,5 %	--	--	88,2 %
N	--	--	--	--	**88,8 %**	--	--	**89,8 %**	--	--	**78,3 %**
GEN	--	--	--	--	**0,0 %**	--	--	**0,0 %**	--	--	**0,0 %**
	--	--	--	--		--	--		--	--	
FLU3	--	--	--	--	**69,0 %**	--	--	**79,9 %**	--	--	**81,9 %**
X	--	--	--	--	**88,0 %**	--	--	**93,3 %**	--	--	**88,3 %**
A	--	--	--	--	88,5 %	--	--	93,6 %	--	--	87,8 %
B	--	--	--	--	82,8 %	--	--	86,2 %	--	--	86,2 %
C	--	--	--	--	88,9 %	--	--	100,0 %	--	--	100,0 %
Y	--	--	--	--	**84,4 %**	--	--	**90,3 %**	--	--	**89,0 %**
A	--	--	--	--	78,1 %	--	--	85,1 %	--	--	82,6 %
B	--	--	--	--	88,0 %	--	--	93,6 %	--	--	91,6 %

C	--	--	--	--	89,5 %	--	--	93,4 %	--	--	97,4 %
Z1	--	--	--	--	**73,7 %**	--	--	**82,2 %**	--	--	**80,9 %**
A	--	--	--	--	67,7 %	--	--	76,0 %	--	--	74,0 %
B	--	--	--	--	82,2 %	--	--	89,9 %	--	--	85,3 %
C	--	--	--	--	74,1 %	--	--	83,7 %	--	--	86,7 %
Z2	--	--	--	--	**62,3 %**	--	--	**76,4 %**	--	--	**81,6 %**
A	--	--	--	--	63,8 %	--	--	72,4 %	--	--	83,2 %
B	--	--	--	--	75,3 %	--	--	85,6 %	--	--	88,3 %
C	--	--	--	--	60,3 %	--	--	75,2 %	--	--	80,5 %
N	--	--	--	--	**75,5 %**	--	--	**81,0 %**	--	--	**76,3 %**
Total	--	--	--	--	**76,1 %**	--	--	**84,7 %**	--	--	**85,3 %**

Absolute values are removed because of confidential reasons

APPENDIX 3: LOCALLY NON –MOVING ITEMS VALUE BY GLOBAL CATEGORY AND LOCATION IN 15TH OF DEC

Global Category	FLU1						FLU1 Total
	Site		Van		WH		
X	--	20,7 %	--	8,2 %	--	71,1 %	--
Y	--	10,4 %	--	25,1 %	--	64,6 %	--
Z1	--	8,4 %	--	6,4 %	--	85,2 %	--
Z2	--	35,5 %	--	7,9 %	--	56,6 %	--
N	--	11,0 %	--	6,7 %	--	82,3 %	--
Local	--	32,9 %	--	4,6 %	--	62,4 %	--
Total	--	**28,0 %**	--	**6,1 %**	--	**66,0 %**	--

Global Category	FLU2						FLU2 Total
	Site		Van		WH		
X	--	15,8 %	--	68,2 %	--	16,0 %	--
Y	--	11,4 %	--	40,9 %	--	47,6 %	--
Z1	--	8,7 %	--	29,8 %	--	61,5 %	--
Z2	--	8,9 %	--	12,2 %	--	78,9 %	--
N	--	3,3 %	--	13,4 %	--	83,3 %	--
Local	--	3,1 %	--	18,8 %	--	78,1 %	--
Total	--	**7,5 %**	--	**23,7 %**	--	**68,8 %**	--

Global Category	FLU3						FLU3 Total
	Site		Van		WH		
X	--	48,9 %	--	17,8 %	--	33,3 %	--
Y	--	43,4 %	--	1,3 %	--	55,3 %	--
Z1	--	36,2 %	--	2,2 %	--	61,6 %	--
Z2	--	5,8 %	--	2,0 %	--	92,2 %	--
N	--	5,2 %	--	0,5 %	--	94,3 %	--
Local	--	22,4 %	--	2,8 %	--	74,8 %	--
Total	--	**18,8 %**	--	**2,1 %**	--	**79,1 %**	--

Global Category	Total						Total
	Site		Van		WH		
X	--	25,4 %	--	42,1 %	--	32,5 %	--
Y	--	18,2 %	--	29,8 %	--	52,0 %	--
Z1	--	15,5 %	--	18,7 %	--	65,9 %	--
Z2	--	12,0 %	--	9,1 %	--	78,9 %	--
N	--	5,3 %	--	7,6 %	--	87,1 %	--
Local	--	29,4 %	--	4,5 %	--	66,0 %	--
Total	--	**18,4 %**	--	**11,1 %**	--	**70,6 %**	--

Absolute values are removed because of confidential reasons

APPENDIX 4: AVAILABILITY BY LOCAL AND DIRECT DELIVERIES

	From Local WH			Direct from DC		
Local Category	**Lines not in backorder (+3d)**	**Backorder lines (+3d)**	**Items**	**Lines not in backorder (+3d)**	**Backorder lines (+3d)**	**Items**
FLU1	--	--	--	--	--	--
X	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Y	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Z1	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Z2	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
N	--	--	--	--	--	--
GEN	--	--	--	--	--	--
FLU2	--	--	--	--	--	--
X	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Y	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Z1	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Z2	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
N	--	--	--	--	--	--
GEN	--	--	--	--	--	--
FLU3	--	--	--	--	--	--

X	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Y	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Z1	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
Z2	--	--	--	--	--	--
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
N	--	--	--	--	--	--
Grand Total	--	--	--	--	--	--

Absolute values are removed because of confidential reasons

APPENDIX 5: AVAILABILITY AND FIRST PICK RATES BY DISTRIBUTION CENTER AND EXTERNAL VENDOR

Local Category	External					Distribution Center				
	Items	Lines not in Backorder (+3d)	Backorder Lines (+3d)	First pick available orders	First pick not available orders	Items	Lines not in Backorder (+3d)	Backorder Lines (+3d)	First pick available orders	First pick not available orders
FLU1	--	--	--	--	--	--	--	--	--	--
X	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Y	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Z1	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Z2	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
N	--	--	--	--	--	--	--	--	--	--
GEN	--	--	--	--	--	--	--	--	--	--
FLU2	--	--	--	--	--	--	--	--	--	--
X	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Y	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Z1	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Z2	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
N	--	--	--	--	--	--	--	--	--	--

GEN	--	--	--	--	--	--	--	--	--	--
FLU3	--	--	--	--	--	--	--	--	--	--
X	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Y	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Z1	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
Z2	--	--	--	--	--	--	--	--	--	--
A	--	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--	--
N	--	--	--	--	--	--	--	--	--	--
Grand Total	--	--	--	--	--	--	--	--	--	--

Absolute values are removed because of confidential reasons

APPENDIX 6: NEW STOCK LEVELS

Local category	Items	Trans-actions	COGS	Average Stock	New Stock Value	Stock value dif-ference	New TIDS	TIDS differ-ence
FLU1	--	--	--	--	--	**-13,5 %**	**178**	**-28**
X	--	--	--	--	--	**0,1 %**	**106**	**0**
A	--	--	--	--	--	0,2 %	104	0
B	--	--	--	--	--	0,0 %	221	0
C	--	--	--	--	--	0,0 %	631	0
Y	--	--	--	--	--	**18,8 %**	**89**	**14**
A	--	--	--	--	--	23,2 %	81	15
B	--	--	--	--	--	2,4 %	149	4
C	--	--	--	--	--	0,7 %	292	2
Z1	--	--	--	--	--	**19,2 %**	**134**	**22**
A	--	--	--	--	--	32,5 %	101	25
B	--	--	--	--	--	2,8 %	258	7
C	--	--	--	--	--	0,8 %	394	3
Z2	--	--	--	--	--	**-36,3 %**	**112**	**-64**
A	--	--	--	--	--	-40,8 %	63	-43
B	--	--	--	--	--	-42,3 %	144	-105
C	--	--	--	--	--	-22,6 %	403	-118
N	--	--	--	--	--	**-9,8 %**	**0**	**0**
GEN	--	--	--	--	--	**0,0 %**	**0**	**0**
	--	--	--	--	--			
FLU2	--	--	--	--	--	**-41,9 %**	**96**	**-69**
X	--	--	--	--	--	**0,0 %**	**44**	**0**
A	--	--	--	--	--	0,0 %	43	0
B	--	--	--	--	--	0,0 %	113	0
C	--	--	--	--	--	0,0 %	726	0
Y	--	--	--	--	--	**33,9 %**	**105**	**26**
A	--	--	--	--	--	49,8 %	90	30
B	--	--	--	--	--	1,6 %	192	3
C	--	--	--	--	--	3,3 %	383	12
Z1	--	--	--	--	--	**14,1 %**	**144**	**18**
A	--	--	--	--	--	16,4 %	128	18
B	--	--	--	--	--	8,7 %	211	17
C	--	--	--	--	--	1,5 %	589	9
Z2	--	--	--	--	--	**-67,1 %**	**38**	**-78**
A	--	--	--	--	--	-65,0 %	25	-47
B	--	--	--	--	--	-72,5 %	45	-118
C	--	--	--	--	--	-63,6 %	118	-206
N	--	--	--	--	--	**-45,0 %**	**0**	**0**

FLU3	--	--	--	--	--	**-20,2 %**	**150**	**-38**
X	--	--	--	--	--	**0,2 %**	**79**	**0**
A	--	--	--	--	--	0,2 %	75	0
B	--	--	--	--	--	0,0 %	169	0
C	--	--	--	--	--	0,0 %	95	0
Y	--	--	--	--	--	**9,3 %**	**86**	**7**
A	--	--	--	--	--	10,9 %	78	8
B	--	--	--	--	--	3,8 %	142	5
C	--	--	--	--	--	0,0 %	213	0
Z1	--	--	--	--	--	**36,0 %**	**89**	**23**
A	--	--	--	--	--	52,1 %	73	25
B	--	--	--	--	--	4,1 %	217	9
C	--	--	--	--	--	1,2 %	325	4
Z2	--	--	--	--	--	**-39,5 %**	**95**	**-62**
A	--	--	--	--	--	-35,9 %	65	-37
B	--	--	--	--	--	-45,4 %	114	-95
C	--	--	--	--	--	-38,0 %	244	-149
N	--	--	--	--	--	**-23,7 %**	**0**	**0**
Grand Total	--	--	--	--	--	**-23,7 %**	**143**	**-44**

Absolute values are removed because of confidential reasons